FIRE AND THE ATOMIC BOMB

Fire Research Bulletin No. 1

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH
AND FIRE OFFICES' COMMITTEE

FIRE RESEARCH

BULLETIN NO. 1

FIRE AND THE ATOMIC BOMB

BY

D. I. LAWSON, M.Sc., M.I.E.E., F.Inst.P.

LONDON: HER MAJESTY'S STATIONERY OFFICE
1954

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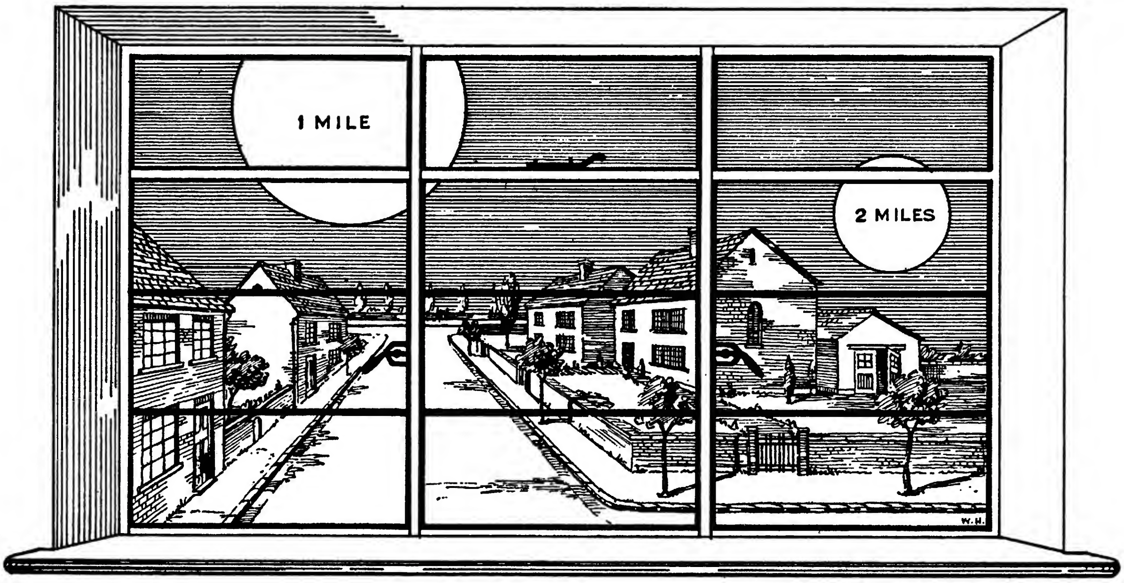
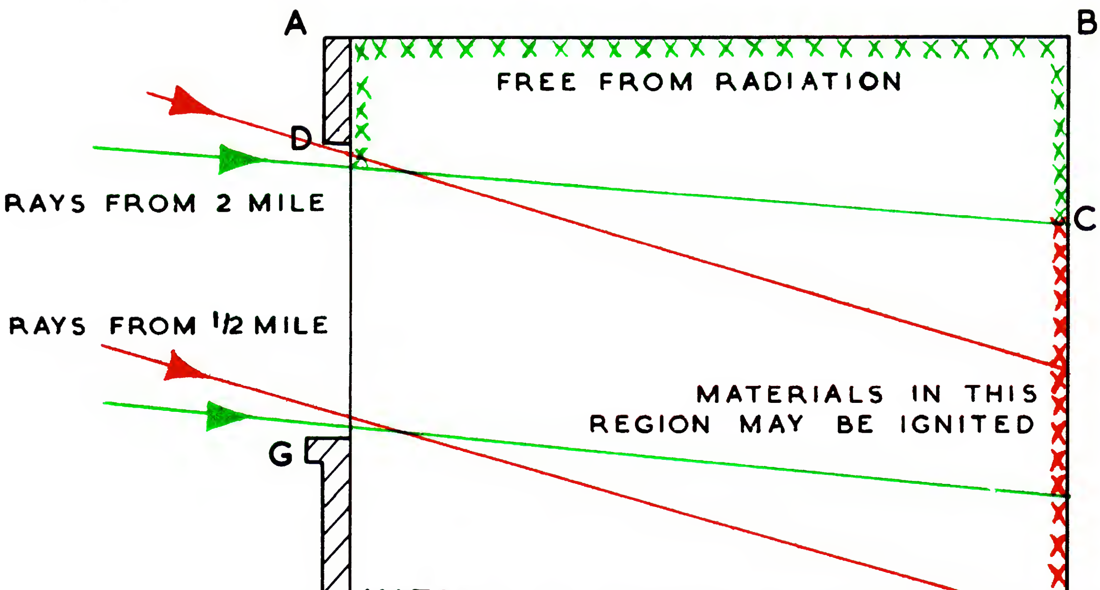
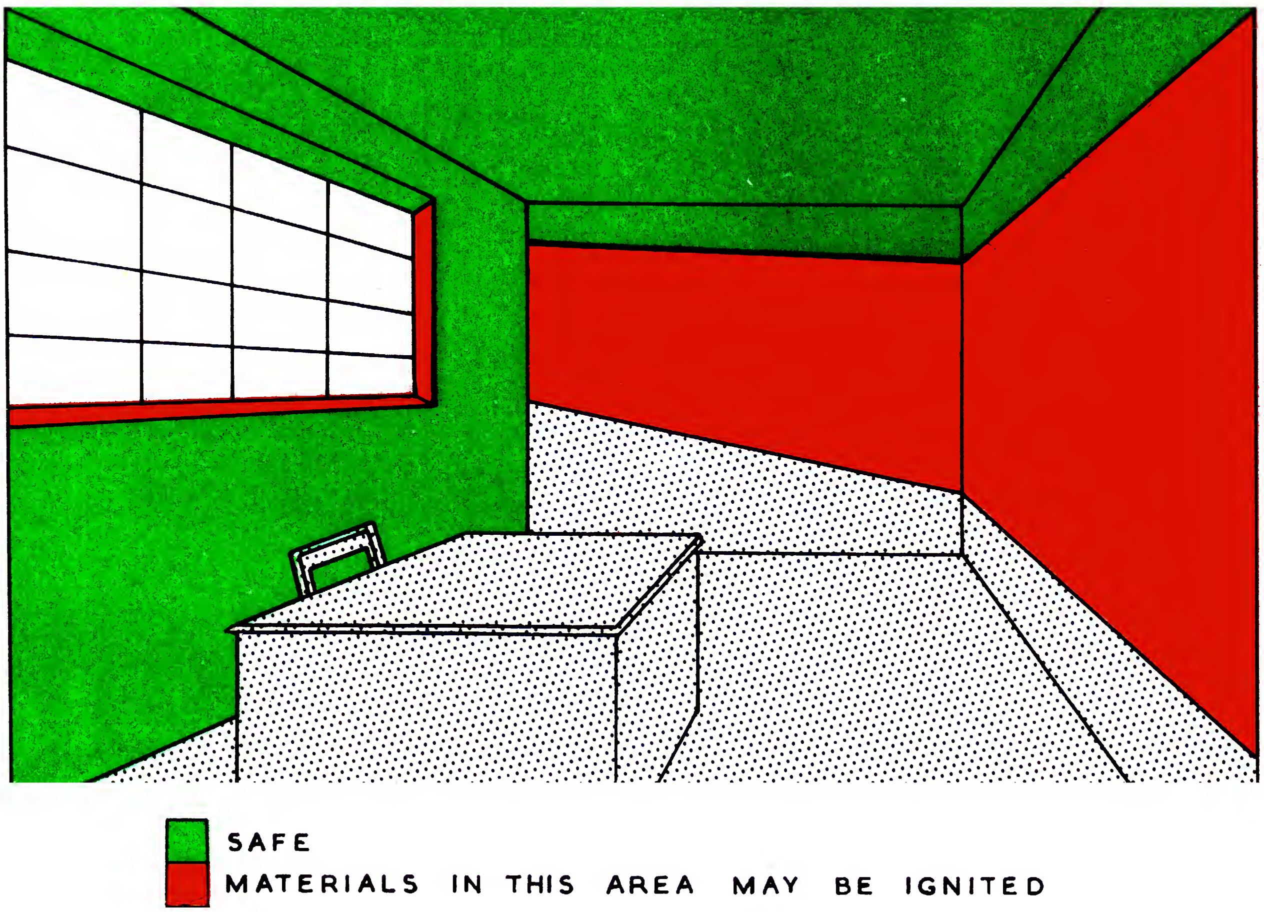


APPARENT POSITION OF FIRE BALL
(Height of burst 600 ft.)



HAZARDS OF IGNITION BY FLASH
OF VARIOUS AREAS IN A ROOM



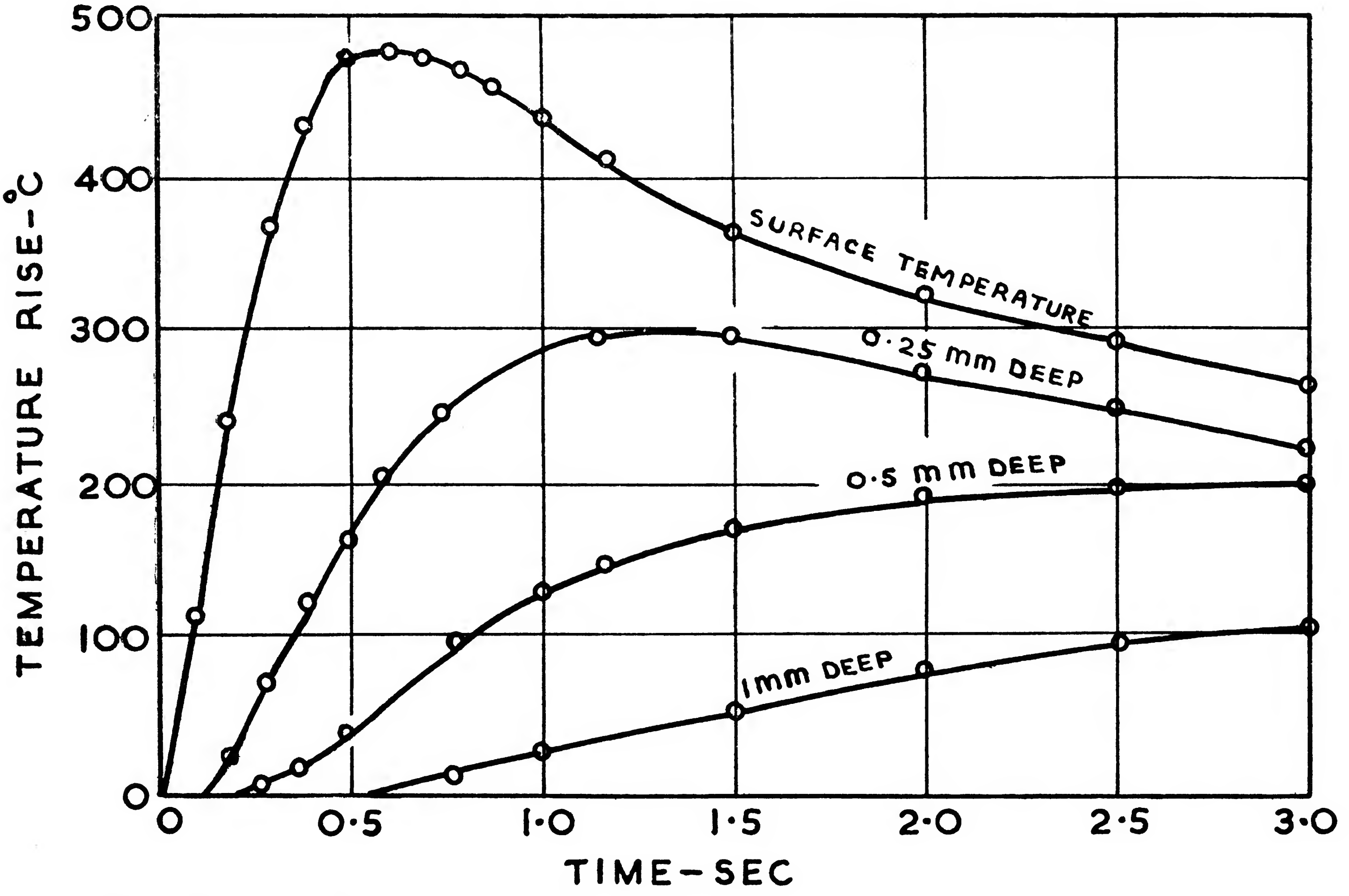
PAGE 5:

The amount of heat received by unit area of a surface in one second provides a convenient unit for measuring radiation. The scientific unit of heat is the calorie. This is the amount of heat required to raise the temperature of one gramme of water by one centigrade degree.

TABLE 1

THE EFFECT OF VARIOUS INTENSITIES OF RADIATION

Sensation or effect	Intensity cal/cm²/sec
Summer sunshine in England	0·016
Pain after 3 sec	0·25



20 KT TIME-TEMPERATURE CURVES FOR MAHOGANY WHEN IRRADIATED WITH A PEAK INTENSITY OF 5·9 CAL/CM²/SEC

PAGE 13:

The radiation falling on any material will heat up the surface and if the radiation is sufficiently intense to bring the surface to a temperature of about 500°C, it will burst into flames. Two factors tend to prevent this : first, as soon as the surface becomes hot it proceeds to lose heat by conduction to the bulk of the material behind the surface, and secondly, heat is lost by the increased radiation from the surface.

. . . the water has to be heated and finally vaporized at 100°C before the temperature of the wood can rise to the ignition point.

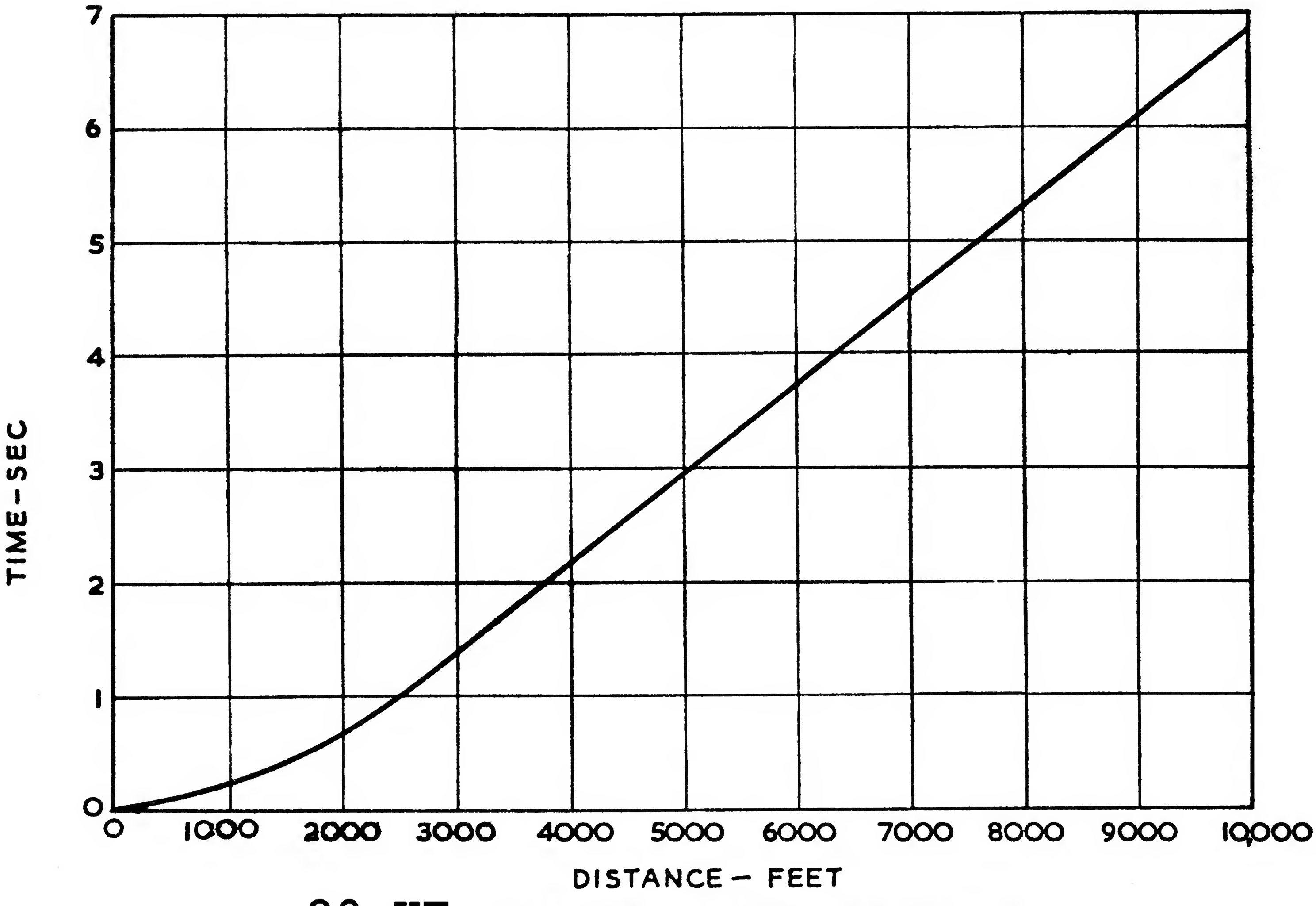
PAGES 13-14:

It seems unlikely that flat wooden surfaces exposed to radiation from the bomb will give rise to a continuing fire.

. . . The temperature below the surface falls away very rapidly. Once the surface is ignited, the material will burn to a depth at which a temperature of 250°C has been reached. It will be seen that the burning is very superficial and does not penetrate to a depth of more than 0·4 mm ; this would not, in all probability, give rise to a continuing fire.

THE PHYSIOLOGICAL EFFECT OF HEAT RADIATION

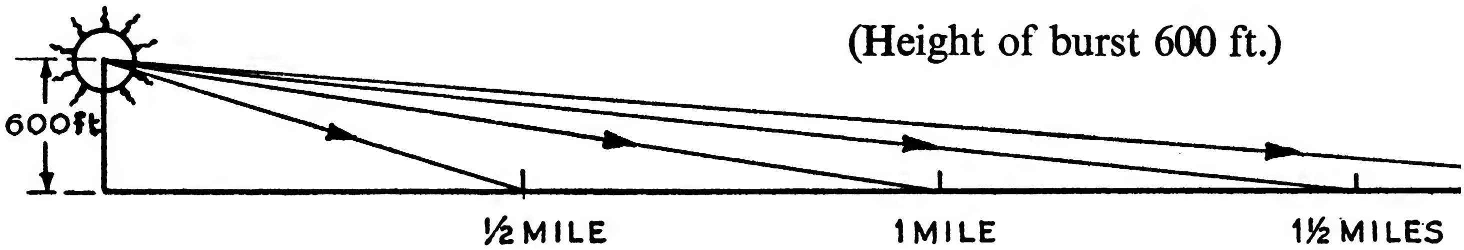
If a sufficient quantity of heat radiation falls on the human skin, burns will result which are similar to those obtained by handling hot bodies. These, of course, may be prevented by covering the exposed parts of the skin with some material which is not readily flammable, for example leather or woollen gloves would be suitable for the hands, and a woollen or treated cotton Balaclava for the face. Estimations have been made by Buettner of the intensity of radiation necessary to produce permanent tissue necrosis at various depths in the skin for exposures of 2 seconds to constant radiation intensities of 1·0, 1·5, 2·0, 2·5, and 3·0 cal/cm^2/sec ; the results indicate that necrosis will occur up to 0·05, 0·24, 0·42, 0·56, and 0·66 mm.



20 KT TIME OF ARRIVAL OF BLAST

PAGE 19:

It is not likely that fires will be started on the exterior surfaces of buildings. Doors and window frames may inflame momentarily, but as we have seen, it is unlikely that they will cause continuing fires. The main danger will come from the materials usually found indoors. The walls of the buildings are, of course, opaque to heat and light radiation, so that this could only enter by means of windows or doors that open directly to the outside.



DIRECTION OF HEAT FLASH RAYS AT VARIOUS DISTANCES

The first fire precaution is to keep as far as possible all readily flammable materials outside the danger zone. These include papers, textiles, upholstery, etc. Plane wooden surfaces will not cause a continuing fire and it would only be necessary to move furniture if it were upholstered. The second precaution is to try to stop the heat radiation entering the room, and this can be done, for example, by fixing some incombustible board across the window space. Any board which is opaque to light radiation will also form a barrier to the heat.

PAGE 21:

Glass will pass nearly all visible radiation, that is why it can be seen through ; but it is quite efficient at stopping heat radiation, and will in fact absorb about two-thirds of that falling on it. The absorption of glass for both heat and light radiation can be improved by coating it with white paint or whitewash and when the coverage is 14 sq. ft./lb., the glass will pass only one-fifth of the radiation falling on it.

PAGE 25:

Curtains and blackout may be treated with a solution of boric acid and borax. This will prevent the ignition of these cotton fabrics during the flash period until the intensity has been raised by about 40 per cent over that normally required for ignition, but more important still, it will remove the chance of a continuing fire. This solution would not, of course, be suitable for the treatment of upholstery or papers which it is necessary to leave lying about. These should be covered by sheets treated with borax-boric acid solution, woollen blankets, or polyvinyl chloride sheeting, or in fact any material which is not readily ignited. If the suggested treatments are carried out white cotton will require an intensity of about 4·9 cal/cm²/sec before ignition takes place. Five times as much radiation as this could be allowed to fall on the glass window before ignition takes place, as four-fifths would be stopped by the treated glass.

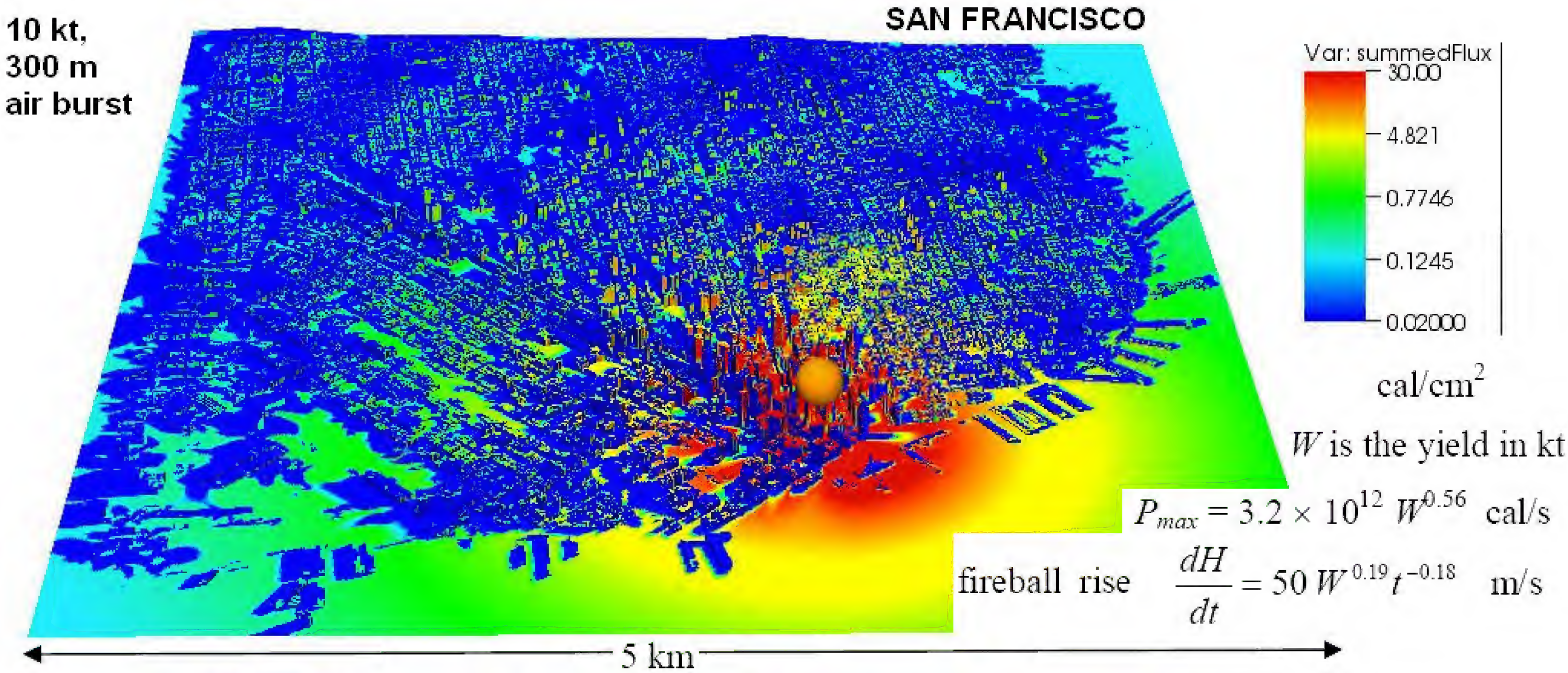
City skyline shielding in an air burst at 600 ft over Birmingham, 1952. Over 50% of the buildings were shielded, preventing a firestorm (144:1 scale model).

SOURCE: George R. Stanbury, The Fire Situation After an Attack on a British City, Technical and Tactical Study Courses, May, June and July 1952, Fire Service College, London: The Home Office (Fire Service Department).

Thermal Radiation from Nuclear Detonations in Urban Environments

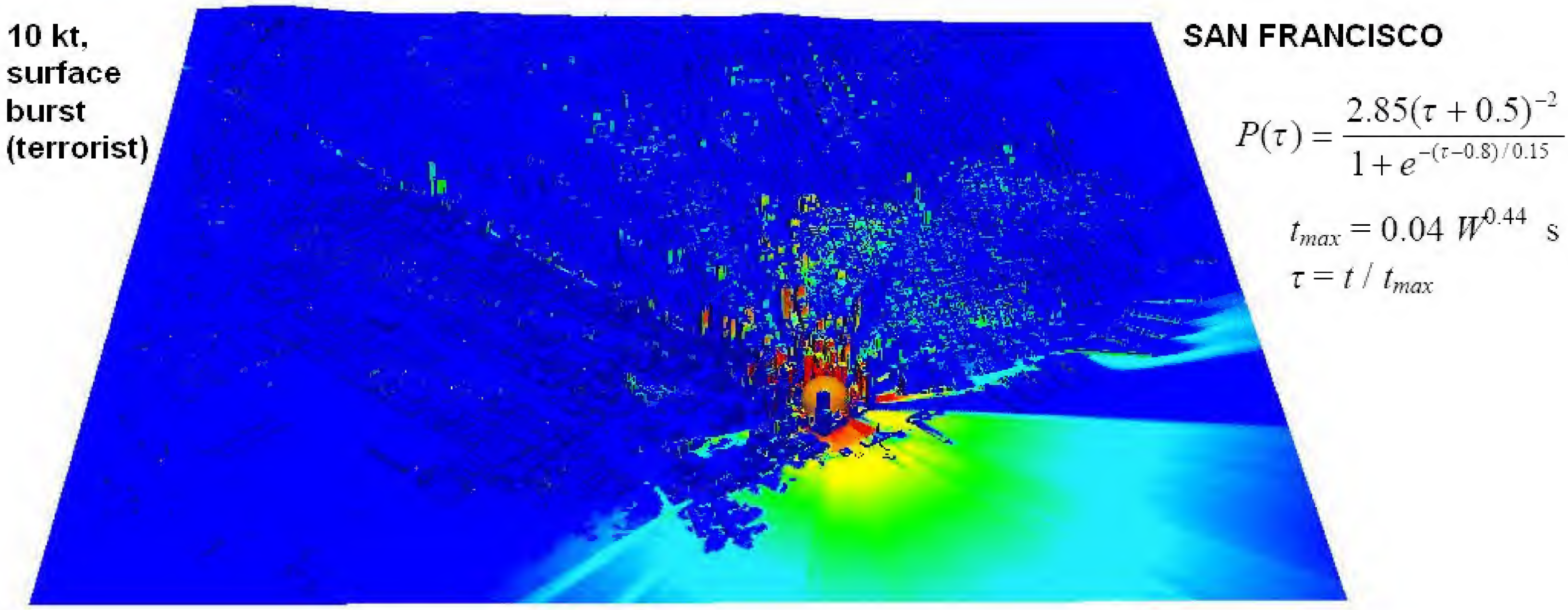
R. E. Marrs, W. C. Moss, and B. Whitlock
Lawrence Livermore National Laboratory

UCRL-TR-231593
June 7, 2007



$$P_{max} = 3.2 \times 10^{12}\ W^{0.56} \text{ cal/s}$$

$$\text{fireball rise} \quad \frac{dH}{dt} = 50\ W^{0.19} t^{-0.18} \text{ m/s}$$



$$P(\tau) = \frac{2.85(\tau + 0.5)^{-2}}{1 + e^{-(\tau - 0.8)/0.15}}$$

$$t_{max} = 0.04\ W^{0.44} \text{ s}$$

$$\tau = t / t_{max}$$

Even without shadowing, the location of most of the urban population within buildings causes a substantial reduction in casualties compared to the unshielded estimates. Other investigators have estimated that the reduction in burn injuries may be greater than 90% due to shadowing and the indoor location of most of the population [6].

We have shown that common estimates of weapon effects that calculate a "radius" for thermal radiation are clearly misleading for surface bursts in urban environments. In many cases only a few unshadowed vertical surfaces, a small fraction of the area within a thermal damage radius, receive the expected heat flux.

HOME OFFICE

CD/SA 121

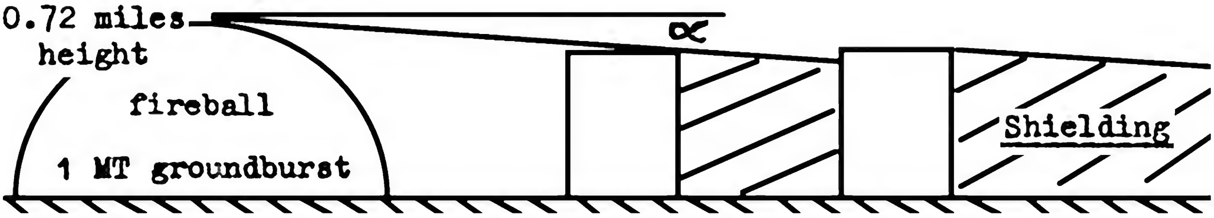
SCIENTIFIC ADVISER'S BRANCH

(Paper at Tripartite Thermal Effects Symposium, Dorking, October 1964)

IGNITION AND FIRE SPREAD IN URBAN AREAS FOLLOWING A NUCLEAR ATTACK

G. R. Stanbury

INITIAL FIRE INCIDENCE



Thermal pulse precedes the blast wave

Assuming that buildings on opposite sides of a street which is receiving heat radiation from a direction perpendicular to its length are of the same height we take the average depth of a floor to be 10 ft.

Effect of Shielding: Estimation of the number of exposed floors

Distance from explosion miles	Angle of arrival α°	Width of street (units of 10 ft.)						
		2	3	4	5	6	7	8
3	$13\frac{1}{2}$	.5	.5	1	1	1.5	1.5	2
4	10	.5	.5	.5	1	1	1.5	1.5
5	8	.5	.5	.5	.5	1	1	1

SPREAD OF FIRE

From last war experience of mass fire raids in Germany it was concluded that the overall spread factor was about 2; i.e. about twice as many buildings were destroyed by fire as were actually set alight by incendiary bombs

Number of fires started per square mile in the fire-storm raid on Hamburg, 27th/28th July, 1943

102 tons H.E.	48 tons, 4 lb. magnesium	40 tons, 30 lb. gel.
100 fires	27,000 bombs	3,000 bombs
	8,000 on buildings	900 on buildings
	1,600 fires	800 fires

2,500 fires in 6,000 buildings

However, the important thing to note is that the total number of fires started in each square mile (2,500) was nearly half that of the total number of buildings; in other words, almost every other building was set on fire

When the figure of 1 in 2 for the German fire storms is compared with the figures for initial fire incidence of $\sim$ 1 in 15 to 30 obtained in the Birmingham and Liverpool studies it can only be concluded that a nuclear explosion could not possibly produce a fire storm.

SECONDARY FIRES FROM BLAST DAMAGE IN LONDON

Fire situation from 1,499 fly bombs in the built-up part of the London Region

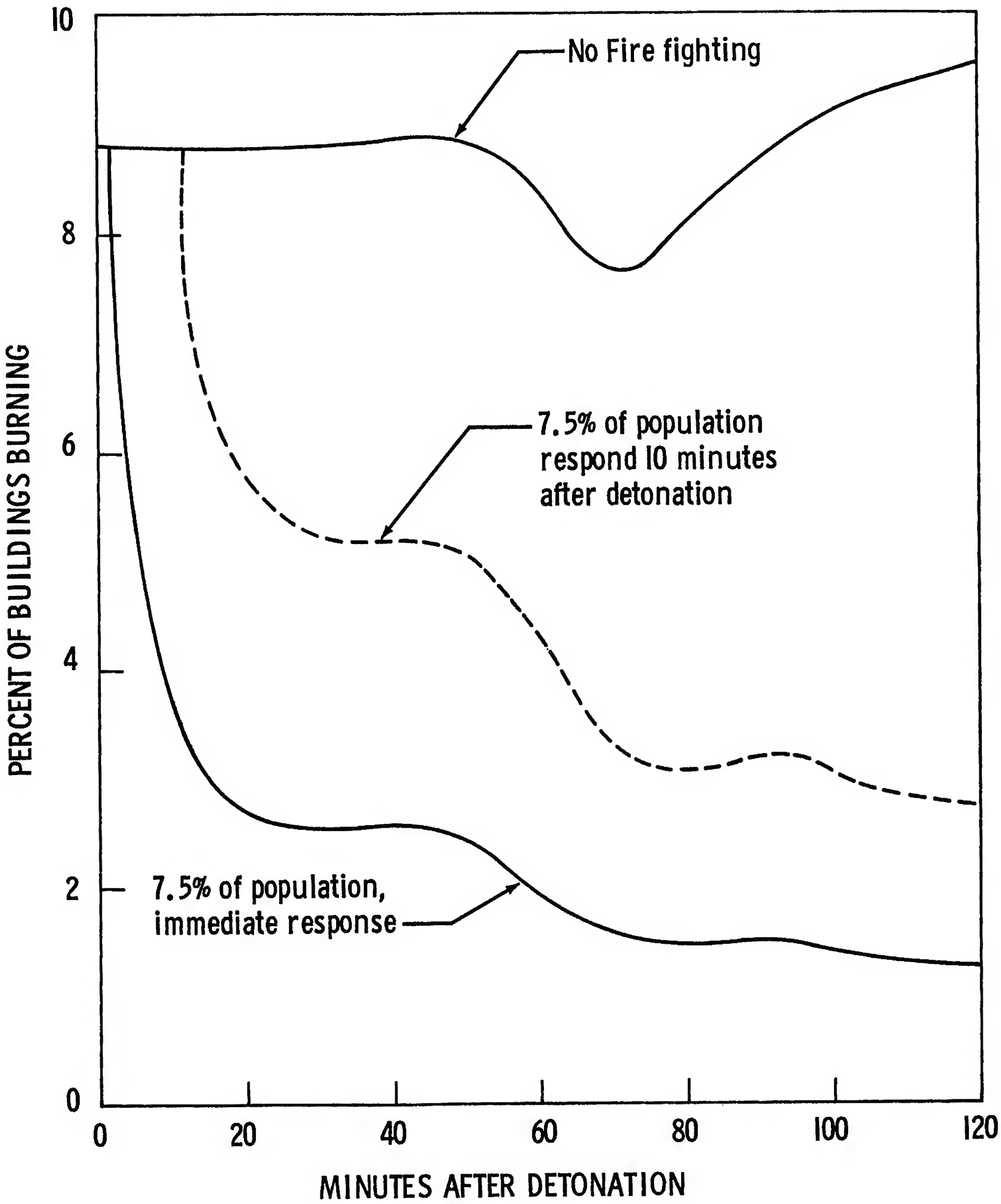
(Fires from 1 ton TNT V1 cruise missiles, 1944)

	Number of fly bombs	Fly Bombs Caused				
		No fire	Small fire	Medium fire	Serious fire	Major fire
Grand Totals	1,499	804	609	75	7	4

The large proportion started no fires at all even in the most heavily built-up areas.

All these fly bombs fell in the summer months of 1944 which were unusually dry. In winter in this country in residential areas there are many open fires which may provide extra sources of ignition. The domestic occupancy is a low fire risk however, and as the proportion of such property in the important City and West End areas is small this should not introduce any serious error. Moreover, in winter, the high atmospheric humidity and the correspondingly high moisture content of timber would tend to retard or even prevent the growth of fire.

Takata, A.N., Mathematical Modeling of Fire Defenses, IITRI, March 1970, AD 705 388.



A. M. Western "Some simplified theories about mass fires". Proceedings of Mass Fire Research Symposium held DASA, Washington D.C. February 1967. DASIAC special report 59 published October 1967.

December 1966 SA/PR 102 (Revised)

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SCIENTIFIC ADVISER'S BRANCH

Some simplified theories about mass fires

by A.M. Western

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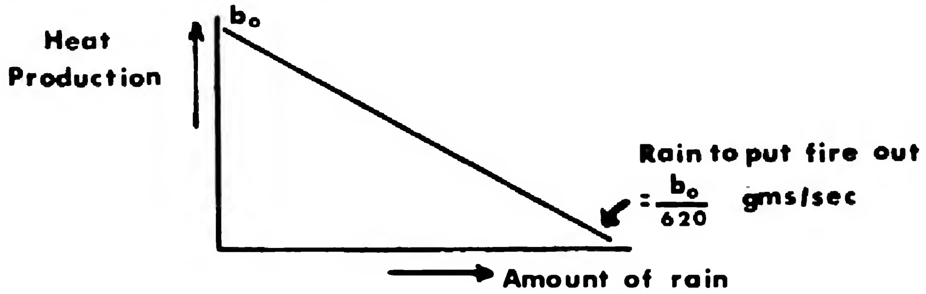
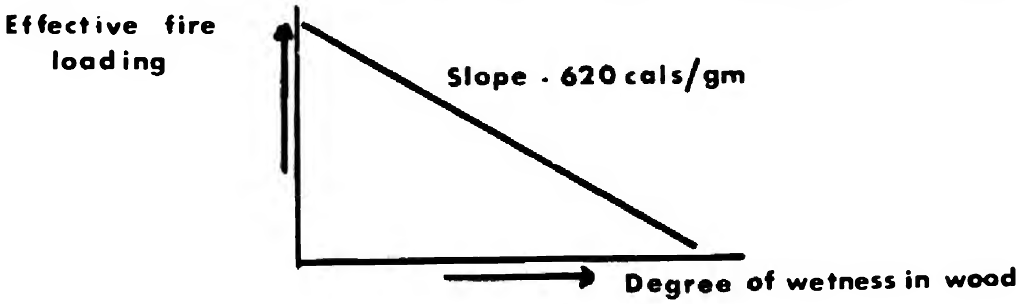
11 If rain falls during a burn, heat production is reduced by 620 cals per gram of water falling on a pile.



12 If wood is wet, fire loading is reduced by 620 cals/gram of water.



March 1968 SA/PR 130

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SCIENTIFIC ADVISER'S BRANCH

Water Calorimeters and Burning Rates in Flambeau 1967

by A. M. Western

Application to Firestorms

14. Historical firestorms were marked by an unusually high casualty rate - about 20% at Hamburg. Why was this so?

As the fire density is increased, the casualty rate starts to climb steeply when the lethal radius about each fire starts to overlap with its neighbour's. Applying this to terraced housing, assume a man is a casualty if his house, the house opposite the front door, and the house opposite the back door, are all alight.

Trapping by heat & fumes

Hence Casualty rate = C = p^3 ....(i)
where p = fraction of houses alight.

For example, if p = 10%, which is reasonable for many group fires, then C = 0.1%, while for p = 60%, which is the order of magnitude of ignitions in Hamburg, C = 22%. Hence this theory could explain the high casualty rate on its own.

Folded newspapers may not take fire, but loosely crumpled ones will. The answer? Get rid of trash.

A wet mop or broom will snuff out small fires. So will a burlap bag or a small rug soaked in water.

Buckets of water and sand are essential.

Water is an effective fire fighting agent because it smothers and cools at the same time.

HOME OFFICE

SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

NUCLEAR WEAPONS

LONDON

HER MAJESTY'S STATIONERY OFFICE

1956

The probable fire situation in a British city

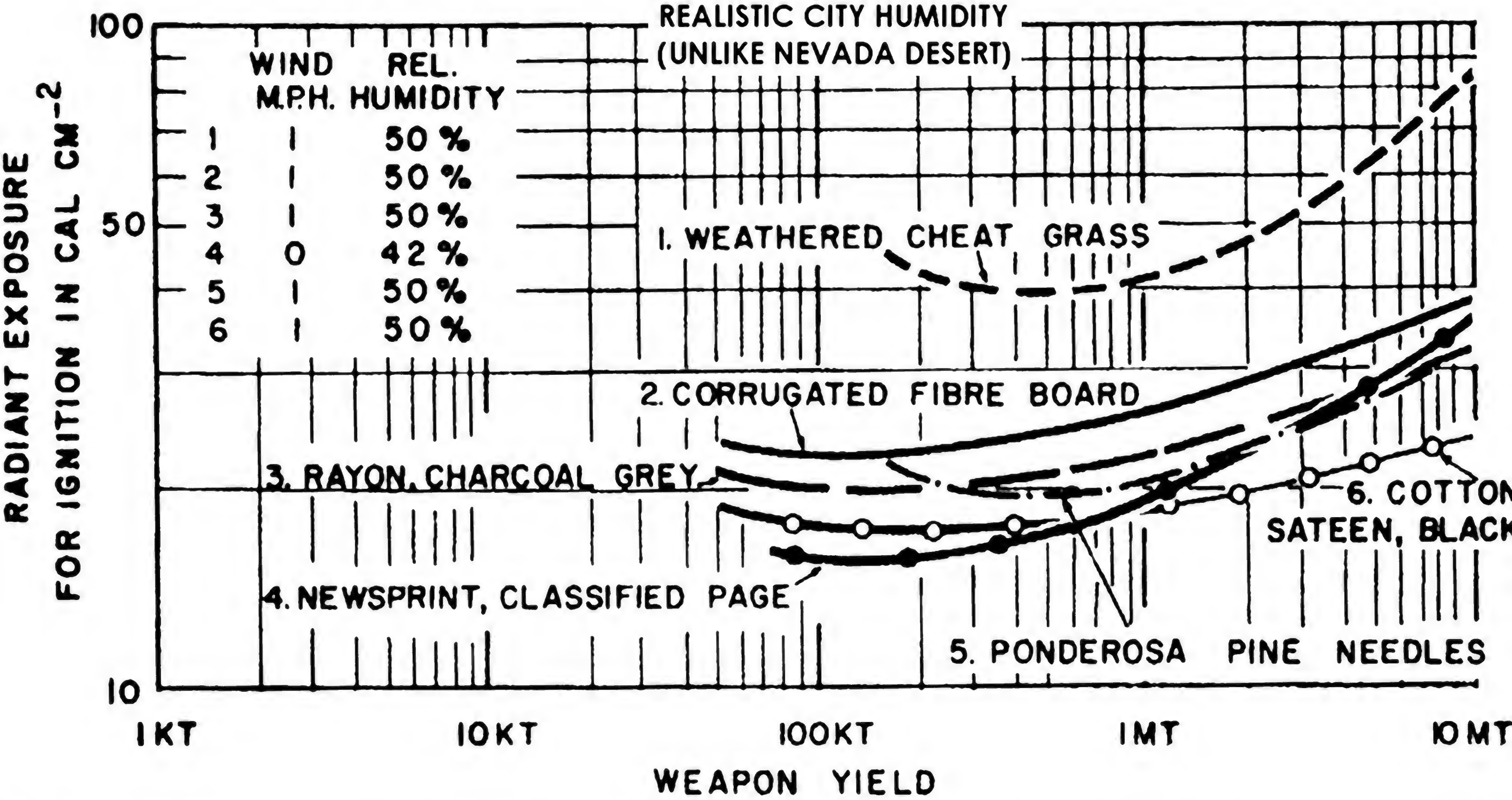
35 Japanese houses are constructed of wood and once they were set on fire they continued to burn even when knocked over. In this country only about 10 per cent. of all the material in the average house is combustible, and under conditions of complete collapse, where air would be almost entirely excluded, it is doubtful whether a fire could continue on any vigorous scale.

40 It seems unlikely from the evidence available that an initial density of fires equivalent to one in every other building would be started by a nuclear explosion over a British city. Studies have shown that a much smaller proportion of buildings than this would be exposed to thermal radiation and even then it is not certain that continuing fires would develop. Curtains may catch fire, but it does not necessarily follow that they will set light to the room; in the last war it was found that only one incendiary bomb out of every six that hit buildings started a continuing fire.

From a 10 megaton bomb, with its longer lasting thermal radiation (see paragraph 21), it takes about 20 calories per square centimetre to start fires because so much of the heat (spread out over the longer emission) is wasted by conduction into the interior of the combustible material and by convection and re-radiation whilst the temperature of the surface is being raised to the ignition point. But the distance at which 20 calories per square centimetre can be produced is only 11 miles, so that the scaling factor for a 10 megaton airburst bomb is therefore 11 and not 22.

43 For a ground burst bomb, however, several other factors contribute to a further reduction in the fire range. Apart from an actual loss of heat by absorption into the ground and from the pronounced shielding effect of buildings, the debris from the crater tends to reduce the radiating temperature of the fireball and a greater proportion of the energy is consequently radiated in the infra red region of the spectrum —this proportion being more easily absorbed by the atmosphere.

44 An important point in relation to personal protection against the effects of hydrogen bomb explosions is that because the thermal radiation lasts so long there is more time for people who may be caught in the open, and who may be well beyond the range of serious danger from blast, to rush to cover and so escape some part of the exposure. For example, people in the open might receive second degree burns (blistering) on exposed skin at a range of 16 miles from a 10 megaton ground burst bomb (8×2—see paragraph 24). If, however, they could take cover in a few seconds they would escape this damage. Moreover, at this range the blast wave would not arrive for another minute and a half so that any effects due to the blast in the open (e.g. flying glass, etc.) could be completely avoided.



"TECHNICAL OBJECTIVE AW-7, CRITICAL RADIANT EXPOSURES FOR PERSISTENT IGNITION", JULY 1960, J. BRACCIAVENTI & F. DEBOLD AD-249476; DASA-1194

UCRL-TR-231593

Thermal radiation from nuclear detonations in urban environments

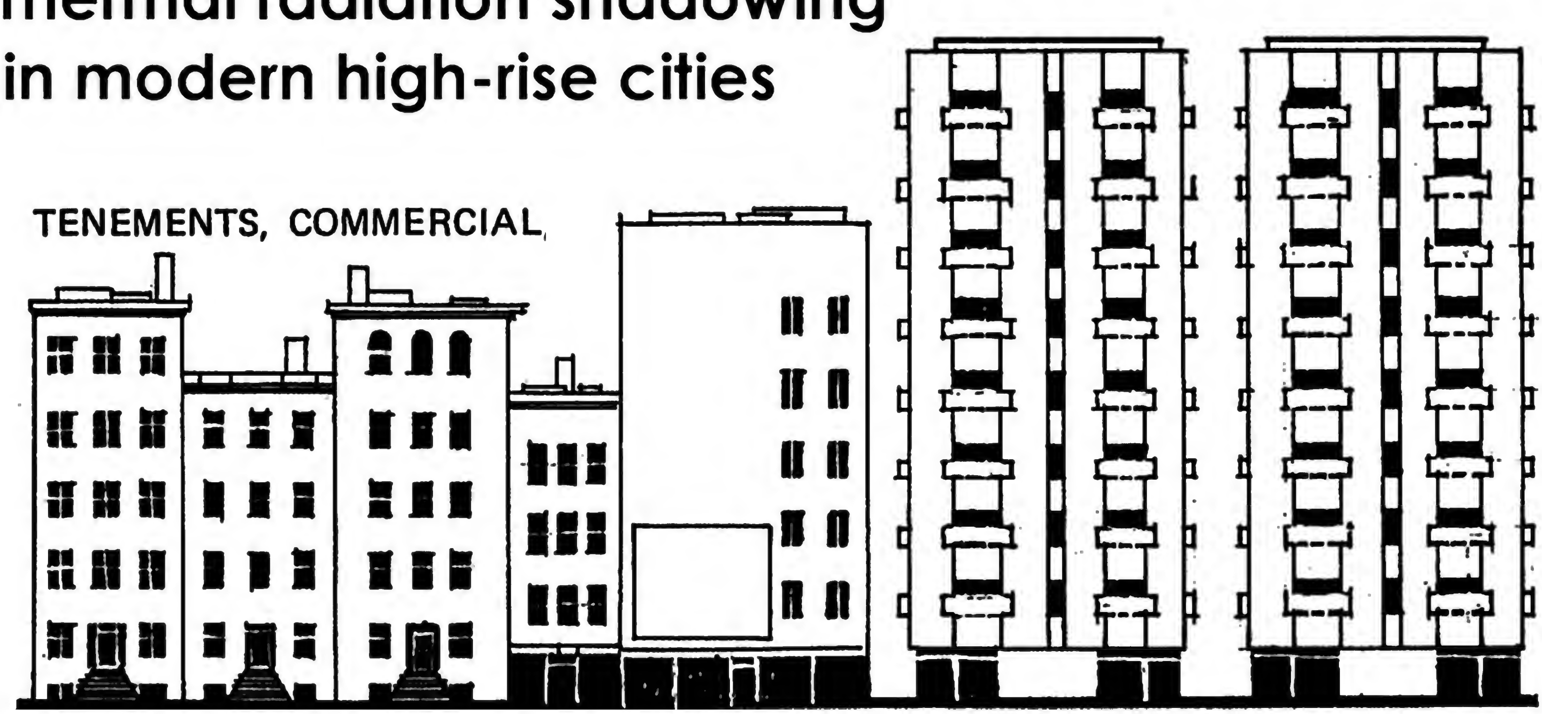
LAWRENCE LIVERMORE NATIONAL LABORATORY

June 7, 2007

Even without shadowing, the location of most of the urban population within buildings causes a substantial reduction in casualties compared to the unshielded estimates. Other investigators have estimated that the reduction in burn injuries may be greater than 90% due to shadowing and the indoor location of most of the population [6].

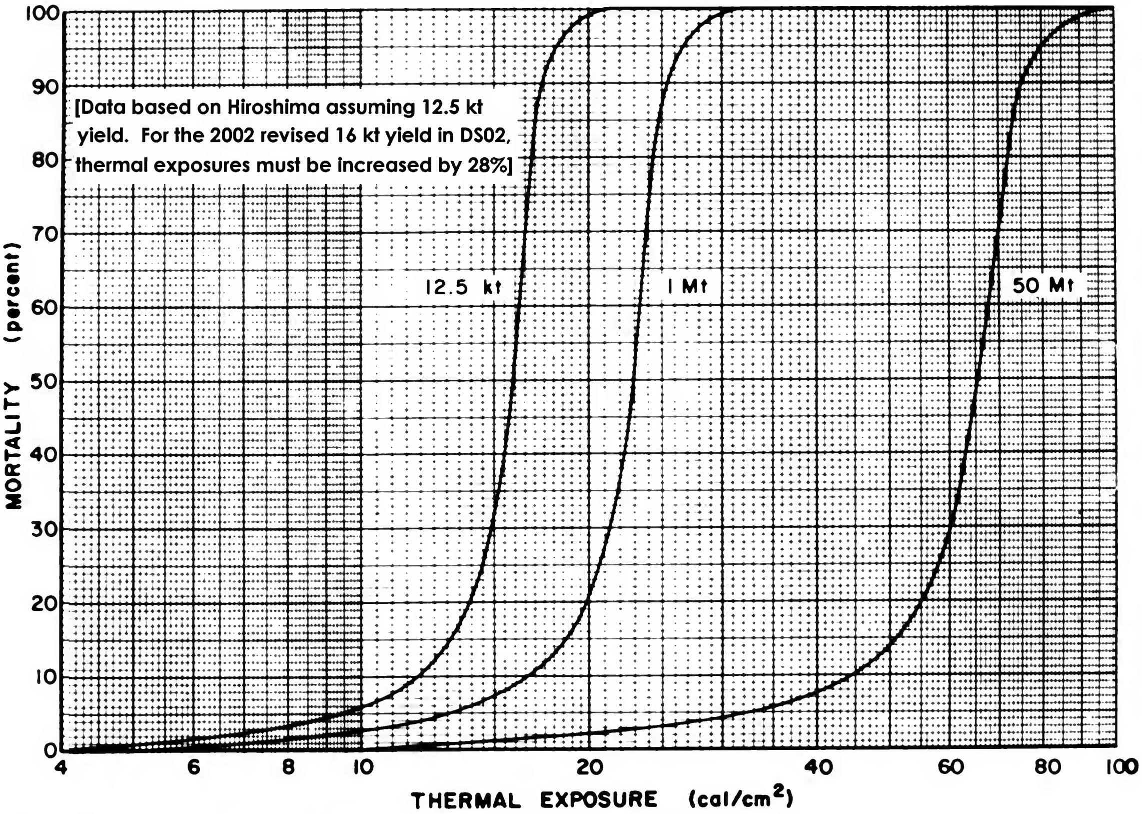
We have shown that common estimates of weapon effects that calculate a "radius" for thermal radiation are clearly misleading for surface bursts in urban environments. In many cases only a few unshadowed vertical surfaces, a small fraction of the area within a thermal damage radius, receive the expected heat flux.

Thermal radiation shadowing in modern high-rise cities



L. Wayne Davis, Donald L. Summers, William L. Baker, and James A. Keller, Prediction of Urban Casualties and the Medical Load from a High-Yield Nuclear Burst, DC-FR-1060, The Dikewood Corporation

PROMPT-THERMAL MORTALITY CURVES FROM SURFACE BURSTS FOR OUTSIDE-UNSHIELDED PERSONS



Unless you are nude outdoors, 6.7 cal/cm^2 is not lethal, contrary to the OTA report!

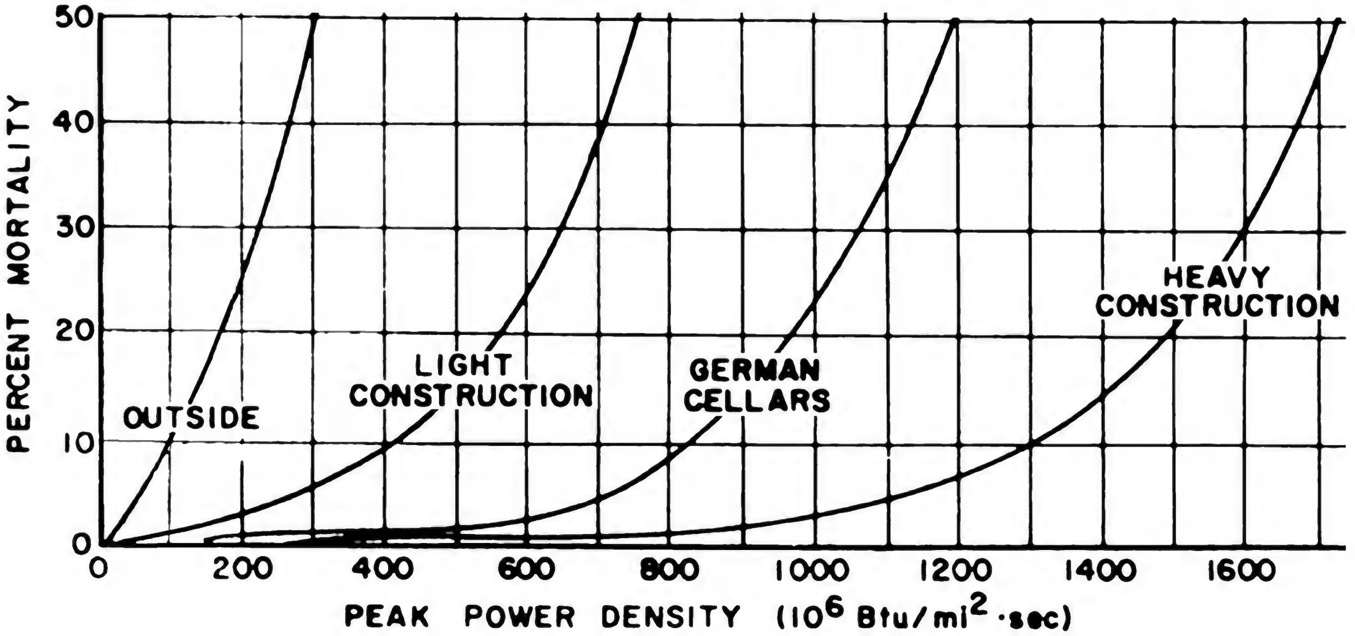
Shirt protection: Nagasaki

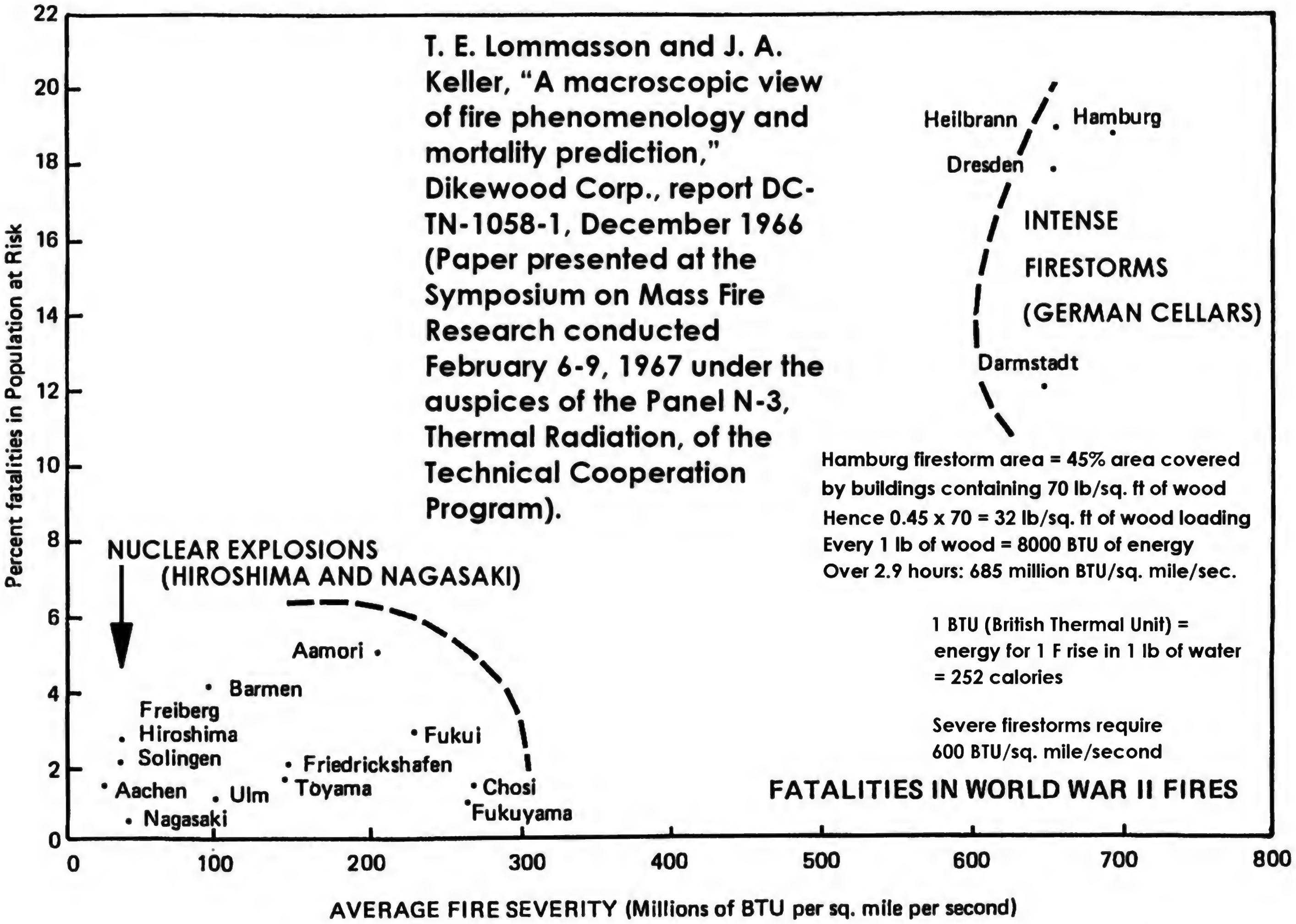
Uniform protection: Hiroshima, "lethal" 6.7 cal/cm^2 !!!

PROTECTION AGAINST RADIANT HEAT. This patient (photographed by Japanese 2 October 1945) was about 6,500 feet from ground zero when the rays struck him from the left. His cap was sufficient to protect the top of his head against flash burns.

Above: Hiroshima soldier only burned on unclothed skin (1946 USSBS report on Hiroshima and Nagasaki, page 16)

FIRE MORTALITY CURVES





Lommasson and Keller, **A Macroscopic View of Fire Phenomenology and Mortality Predictions**, Dikewood Corporation, DC-TN-1058-1, December 1966.

J. A. Keller, A Study of World War II German Fire Fatalities, DC-TN-1050-3, The Dikewood Corporation; April, 1966.

R. Schubert, Examination of Building Density and Fire Loading in the Districts Eimsbuettel and Hammerbrook of the City of Hamburg in the Year 1943 (20 volumes, in German), Stanford Research Institute; January, 1966.

OFFICE OF THE AIR SURGEON

NP-3041

MEDICAL EFFECTS OF ATOMIC BOMBS

The Report of the Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan; Volume VI

By

Ashley W. Oughterson
George V. LeRoy
Averill A. Liebow
E. Cuyler Hammond
Henry L. Barnett
Jack D. Rosenbaum
B. Aubrey Schneider

July 6, 1951
[TIS Issuance Date]

Army Institute of Pathology

UNITED STATES ATOMIC ENERGY COMMISSION
Technical Information Service, Oak Ridge, Tennessee

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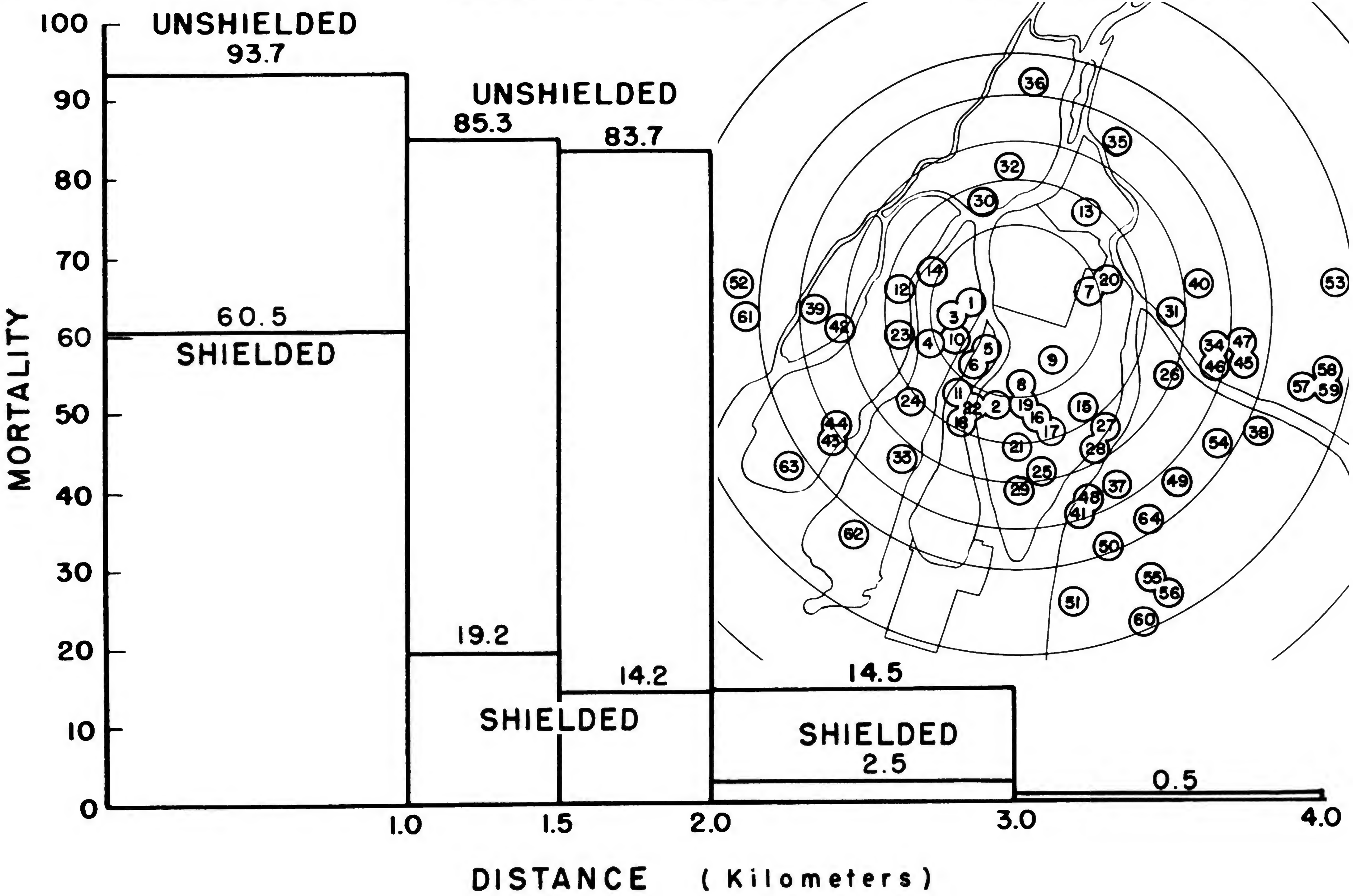
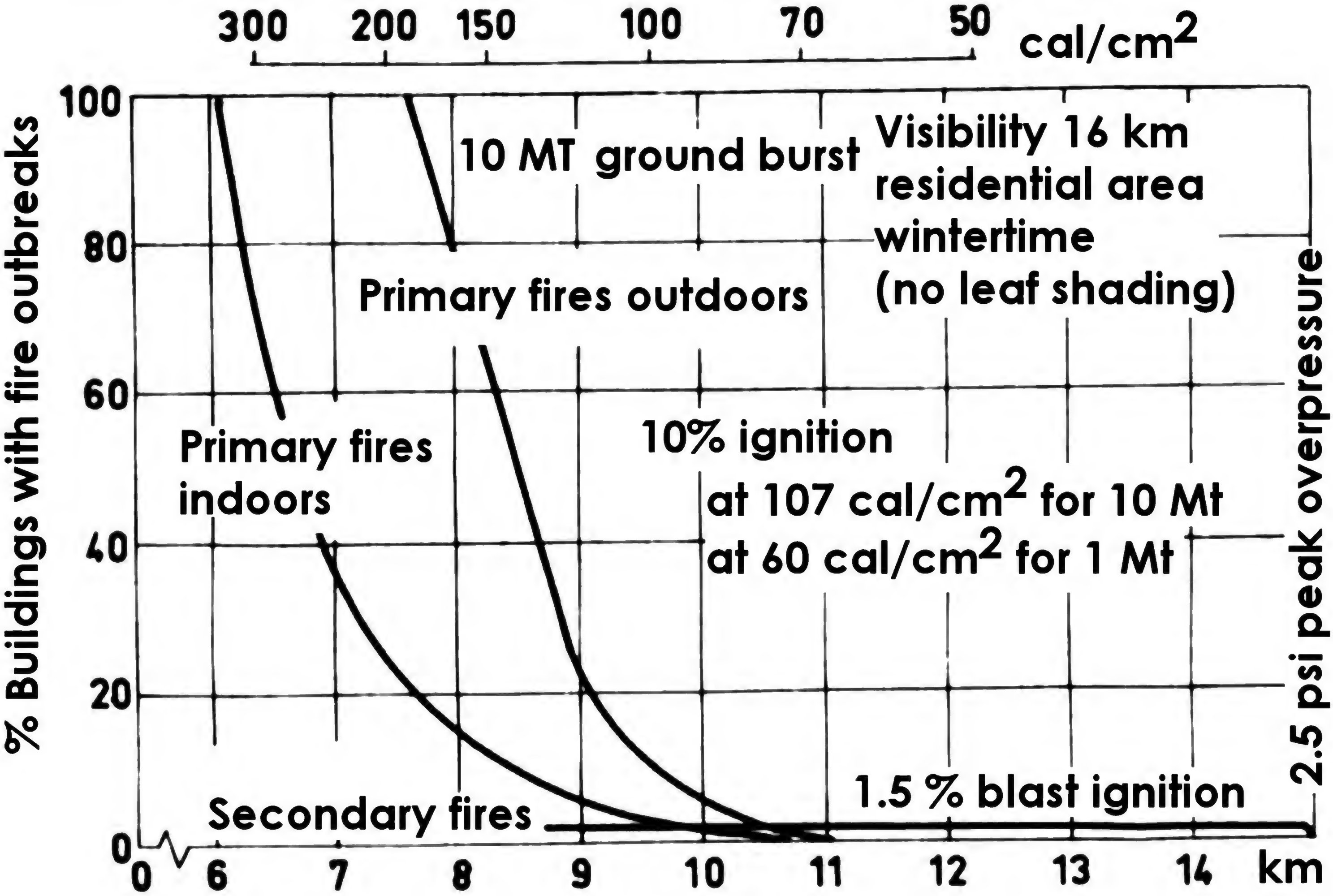
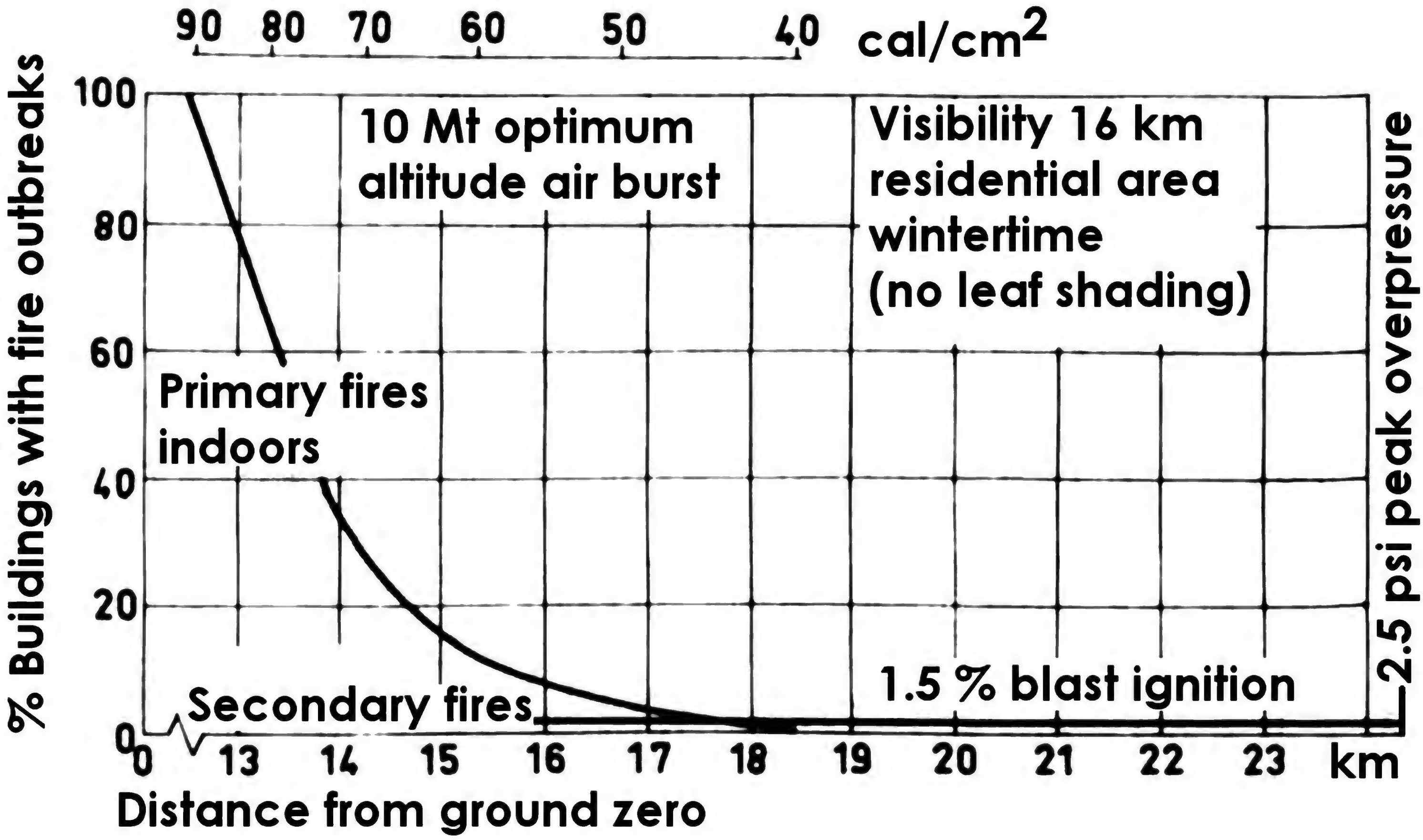


John L. Crain, et al., Supplemental Analysis - Civil Defense Rescue, Stanford Research Institute, AD0625802, 1965.





DNA EM-1
PART I
1 JULY 1972

DEFENSE NUCLEAR AGENCY EFFECTS MANUAL NUMBER 1

CAPABILITIES
OF
NUCLEAR WEAPONS

PART I
PHENOMENOLOGY

HEADQUARTERS
Defense Nuclear Agency
Washington, D.C. 20305

EDITOR
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A parameter that is useful for calculating thermal response of materials is the characteristic thermal response time τ_o, given by the equation

$$\tau_o = \rho C_p L^2/k \text{ sec},$$

where k is thermal conductivity (cal-sec^{-1} cm^{-1}°C^{-1}), ρC_p is heat capacity per unit volume (ρ = density in g-cm^{-3} and C_p = specific heat at constant pressure in cal-g^{-1}°C^{-1}), and L is the thickness, in centimeters, of the layer of material.

The quantity

$$\alpha = \frac{k}{\rho C_p}$$

is called thermal diffusivity (cm^2/sec). Use of this quantity simplies the previous equation to

$$\tau_o = \frac{L^2}{\alpha} \text{ sec.*}$$

For any particular material exposed to a rectangular pulse of length τ, the previous equation can be transformed to give a characteristic thickness

$$\delta = \sqrt{\alpha\tau} \text{ cm.}$$

for which the characteristic time is equal to the pulse duration. If a thick slab of this material is exposed to a pulse of length τ, the temperature rise at the surface is the same as would be produced by uniformly distributing the absorbed thermal energy in a slab of thickness δ, and the peak temperature rise at depth δ in the thick slab is about half as great as the peak temperature rise at the surface.

For example, consider a block of red pine that is exposed to 15 cal/cm^2 from a rectangular pulse of 3 seconds duration. From Table 9-1,

$$\delta = \sqrt{\alpha\tau} = \sqrt{(24 \times 10^{-3})(3)} = 0.085 \text{ cm.}$$

*This equation is useful, but it is by no means exact. The simplified heat-flow analysis from which this equation is derived neglects the effects of radiation and convection heat losses from the surfaces of the exposed sample. It also assumes an isotropic medium, i.e., a medium whose structure and properties in the neighborhood of any point are the same relative to all directions through the point. It also neglects the changes in thermal properties that occur as the exposed material heats, volatilizes, chars, and bursts into flame.

The heat absorbed by the wood before it begins to scorch is equal to the product of the incident radiant energy, Q, and the absorption coefficient, A.

$$\Delta T_s = \frac{QA}{\rho\delta C_p} = \frac{QA}{\rho C_p \sqrt{\alpha\tau}} = \frac{QA}{\rho C_p \sqrt{\tau k/\rho C_p}}.$$

where ΔT_s is the peak temperature rise at the surface. The parameters that define the thermal pulse may be separated from those that define the material properties, and

$$\Delta T_s = \left(\frac{Q}{\sqrt{\tau}}\right)\left(\frac{A}{\sqrt{k\rho C_p}}\right).$$

For a fixed rectangular pulse, $Q/\sqrt{\tau}$ is a constant, and the equation may be written

$$\Delta T_s = (K)\left(\frac{A}{\sqrt{k\rho C_p}}\right).$$

Sustained ignition only occurs when higher radiant exposures raise the temperature throughout the thickness of the cellulose to a level that is sufficiently high to sustain the flow of combustible gases from breakdown of the fuel. It is difficult to supply sufficient energy with short pulses, since a large amount of the energy that is deposited is carried away by the rapid ablation of the thin surface layer. This transient flaming phenomenon is typical of the response of sound wooden boards to a thermal pulse.

Table 9-1. [redacted] Thermal Properties of Materials [redacted]

Materials	Density, ρ (gm/cm^3)	Specific Heat, C_p ($cal/gm \cdot {}^\circ C$)	Conductivity, k ($cal/sec \cdot cm \cdot {}^\circ C$)	Diffusivity, α (cm^2/sec)
Insulating Materials				
Air	9.46×10^{-4}	0.24	0.55×10^{-4}	0.22
Asbestos	0.58	0.20	4.6×10^{-4}	$40. \times 10^{-4}$
Balsa	0.12	0.4	1.2×10^{-4}	$25. \times 10^{-4}$
Brick (common red)	1.8	0.2	$16. \times 10^{-4}$	$18. \times 10^{-4}$
Celluloid	1.4	0.35	5.0×10^{-4}	$10. \times 10^{-4}$
Cotton, sateen, green	0.70	0.35	1.5×10^{-4}	2.5×10^{-4}
Fir, Douglas-				
spring growth	0.29	0.4	$2. \times 10^{-4}$	$17. \times 10^{-4}$
summer growth	1.00	0.4	$5. \times 10^{-4}$	$12. \times 10^{-4}$
Fir, white	0.45	0.4	2.6×10^{-4}	$14. \times 10^{-4}$
Glass, window	2.2	0.2	$19. \times 10^{-4}$	$43. \times 10^{-4}$
Granite	2.5	0.19	$66. \times 10^{-4}$	$140. \times 10^{-4}$
Leather sole	1.0	0.36	3.8×10^{-4}	$11. \times 10^{-4}$
Mahogany	0.53	0.36	3.1×10^{-4}	$16. \times 10^{-4}$
Maple	0.72	0.4	4.5×10^{-4}	$16. \times 10^{-4}$
Oak	0.82	0.4	5.0×10^{-4}	$15. \times 10^{-4}$
Pine, white	0.54	0.33	3.6×10^{-4}	$18. \times 10^{-4}$
Pine, red	0.51	0.4	$5. \times 10^{-4}$	$24. \times 10^{-4}$
Rubber, hard	1.2	0.5	3.6×10^{-4}	$60. \times 10^{-4}$
Teak	0.64	0.4	4.1×10^{-4}	$16. \times 10^{-4}$
Metals (100°C)				
Aluminum	2.7	0.22	0.49	1.0
Cadmium	8.65	0.057	0.20	0.45
Copper	8.92	0.094	0.92	1.1
Gold	19.3	0.031	0.75	1.2
Lead	11.34	0.031	0.081	0.23
Magnesium	1.74	0.25	0.38	0.87
Platinum	21.45	0.027	0.17	0.29
Silver	10.5	0.056	0.96	1.6
Steel, mild	7.8	0.11	0.107	1.2
Tin	6.55	0.056	0.14	0.38
Miscellaneous Materials				
Ice (0°C)	0.92	0.492	$54. \times 10^{-4}$	$120. \times 10^{-4}$
Water	1.00	1.00	$14. \times 10^{-4}$	$14. \times 10^{-4}$
Skin (porcine, dermis, dead)	1.06	0.77	$9. \times 10^{-4}$	$11. \times 10^{-4}$
Skin (human, living, averaged for upper 0.1 cm)	1.06	0.75	$8. \times 10^{-4}$	$30. \times 10^{-4}$
Polyethylene (black)	0.92	0.55	$8. \times 10^{-4}$	$17. \times 10^{-4}$

Thermal flash on forest leaf canopy produces smoke-screen (in Nevada and Pacific nuclear tests), shadowing dry leaf litter

The high degree of shading by tree crowns and stems for detonations at or below the canopy level often may be offset by scattering of burning debris ignited within the fireball. 15-59

Fuels seldom burn vigorously, regardless of wind conditions, when fuel moisture content exceeds about 16 percent. This corresponds to an equilibrium moisture content for a condition of 80 percent relative humidity. 15-60

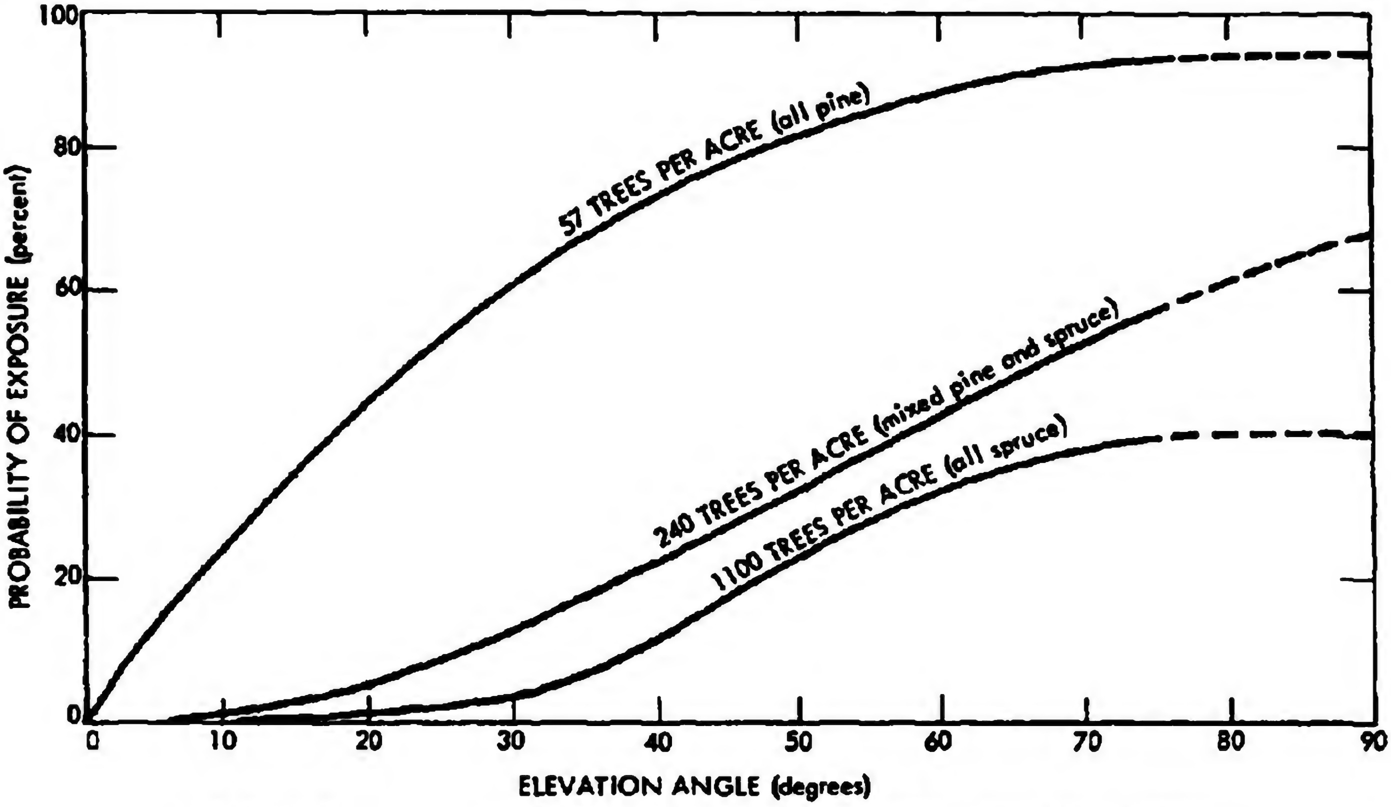

Figure 15-41. Probability of Exposure of Forest Floor for Different Levels of Tree Density

Table 15-13 Burning Durations by Fuel Type

Fuel Type	Violent Burning: Time (min)	Violent Burning: Energy Release (percent)	Residual Burning: Time (min)	Residual Burning: Energy Release (percent)	Total Burning Time
Grass	1.5	90	0.5	10	30 min
Light Brush (12 tons/acre)	2.	60	6.	40	16 hr
Medium Brush (25 tons/acre)	6.	50	24.	50	36 hr
Heavy Brush (40 tons/acre)	10.	40	70.	60	72 hr
Timber	24.	17	157.	83	7 days

Table 15-11[redacted] Criteria of "No-Spread" of Fires [redacted]

Fuel Type	Criteria
All forest fuels	Over 1 inch of snow on the ground at the nearest weather stations.
Grass	Relative humidity above 80 percent.
Brush or hardwoods	0.1 inch of precipitation or more within the past 7 days and: Wind 0-3 mph; relative humidity 60 percent or higher, or Wind 4-10 mph; relative humidity 75 percent or higher, or Wind 11-25 mph; relative humidity 85 percent or higher.
Conifer timber	1. One day or less since at least 0.25 inch of precipitation and: Wind 0-3 mph; relative humidity 50 percent higher, or Wind 4-10 mph; relative humidity 75 percent higher, or Wind 11-25 mph; relative humidity 85 percent or higher. 2. Two to three days since at least 0.25 inch of precipitation and: Wind 0-3 mph; relative humidity 60 percent or higher, or Wind 4-10 mph; relative humidity 80 percent or higher, or Wind 11-25 mph; relative humidity 90 percent or higher. 3. Four to five days since at least 0.25 inch of precipitation and wind 0-3 mph; relative humidity 80 percent or higher. 4. Six to seven days since at least 0.25 inch of precipitation and wind 0-3 mph; relative humidity 90 percent or higher.

[redacted]

shielding from the wind and shading from sunlight by the canopy. The spread or no-spread criteria are summarized in Table 15-11. This table lists the conditions under which fire would not be expected to spread.

[redacted] The criteria of Table 15-11 have been compared to the records of 4,378 wildland fires. Of the fires for which "no spread" would be predicted, 97.8 percent did not spread; only 40 percent of the fires that were predicted to spread actually did spread (at a rate of 0.005 mph or faster). This failure to spread often may be attributable to lack of fuel continuity around the point of origin.

[redacted] The criteria of Table 15-11 are considered to be reliable for American forests and suitably conservative to assure a low level of hazard to friendly forces. On the other hand, the criteria are probably not overly conservative to predict conditions for which enemy forces may be denied forested areas because of fire whenever the local weather history and conditions at the time of

[redacted] SURVIVAL IN FIRE AREAS [redacted]

[redacted] The best documented fire storm in history (but not the one causing the greatest loss of life) occurred in Hamburg, Germany during the night of July 27-28, 1943, as a result of an incendiary raid by Allied forces. Factors that contributed to the fire included the high fuel loading of the area and the large number of buildings ignited within a short period of time.

[redacted] The main raid lasted about 30 minutes. Since the air raid warning and the first high explosive bombs caused most people to seek shelter, few fires were extinguished during the attack. By the time the raid ended, roughly half the buildings in the 5 square-mile fire storm area were burning, many of them intensely. The fire storm developed rapidly and reached its peak in two or three hours.

[redacted] Many people were driven from their shelters and then found that nearly everything was burning. Some people escaped through the streets; others died in the attempt; others returned to their shelters and succumbed to carbon monoxide poisoning.

[redacted] Estimates of the number that were killed range from about 40,000 to 55,000. Most of the deaths resulted from the fire storm. Two equally heavy raids on the same city (one occurred two nights earlier; the other, one night later) did not produce fire storms, and they resulted in death rates that have been estimated to be nearly an order of magnitude lower.

[redacted] More surprising than the number killed is the number of survivors. The population of the fire storm area was roughly 280,000. Estimates have been made that about 45,000 were rescued, 53,000 survived in non-basement shelters, and 140,000 either survived in basement shelters or escaped by their own initiative.

9-25 Causes of Death [redacted]

[redacted] The evidence that can be reconstructed from such catastrophes as the Hamburg fire storm indicates that carbon monoxide and excessive heat are the most frequent causes of death in mass fires. Since the conditions that offer protection from these two hazards generally provide protection from other hazards as well, the following discussion is limited to these two causes of death.

[redacted] *Carbon Monoxide.* Burning consists of a series of physical and chemical reactions. For most common fuels, one of the last of the reactions is the burning of carbon monoxide to form carbon dioxide near the tips of the flames. If the supply of air is limited, as it is likely to be if the fire is in a closed room or at the bottom of a pile of debris from a collapsed building, the carbon monoxide will not burn completely. Fumes from the fire will contain a large amount of this tasteless, odorless, toxic gas.

[redacted] During the Hamburg fire, many basement shelters were exposed to fumes. Imperfectly fitting doors and cracks produced by exploding bombs allowed carbon monoxide to penetrate these shelters. The natural positions of many of the bodies recovered after the raid indicated that death had often come without warning, as is frequently the case for carbon monoxide poisoning.

[redacted] Carbon monoxide kills by forming a more stable compound with hemoglobin than either oxygen or carbon dioxide will form. These latter are the two substances that hemoglobin ordinarily carries through the blood stream. Carbon monoxide that is absorbed by the blood reduces the oxygen carrying capacity of the blood, and the victim dies from oxygen deficiency.

[redacted] As a result of the manner that carbon monoxide acts, it can contribute to the death of a person who leaves a contaminated shelter to attempt escape through the streets of a burning city. A person recovering from a moderate case of carbon monoxide poisoning may feel well while he is resting, but his blood may be unable

[redacted]

to supply the oxygen his body needs when he exerts himself. After the air raid at Hamburg. victims of carbon monoxide poisoning. apparently in good health. collapsed and died from the strain of walking away from a shelter. It is suspected that many of the people who died in the streets of Hamburg were suffering from incipient carbon monoxide poisoning.

[redacted] *Heat.* The body cools itself by perspiration. When the environment is so hot that this method fails. body temperature rises. Shortly thereafter, the rate of perspiration decreases rapidly. and. unless the victim finds immediate relief from the heat, he dies of heat exhaustion. Death from excessive heat may occur in an inadequately insulated shelter: it also may occur in the streets if a safe area cannot be located in a short time.

9-26 Shelters [redacted]

[redacted] The results of the Hamburg fire storm illustrate the value of shelters during an intense mass fire. The public air raid shelters in Hamburg had very heavy walls to resist large bombs. Reinforced concrete three feet thick represented typical walls. Some of these shelters were fitted with gas proof doors to provide protection from poison gas. These two features offered good protection from the heat and toxic gases generated by the fire storm.

[redacted] The public shelters were of three types:

- *Bunkers.* These were large buildings of several shapes and sizes, designed to withstand direct hits by large bombs. The fire storm area included 19 bunkers designed to hold a total of about 15,000 people. Probably twice this number occupied the bunkers during the fire storm, and all of these people survived.
- *Splinterproof Shelters.* These were long single story shelters standing free of other buildings and protected by walls of reinforced concrete at least 2-1/2 feet thick. No deaths resulting from the fire storm were reported among occupants of these shelters. These structures were not gasproof. Distance from burning structures and low height of the shelters probably provided protection from carbon monoxide.
- *Basement Shelters.* The public shelters that were constructed in large basements had ceilings of reinforced concrete 2 to 5 feet thick. Although reports indicate that some of the occupants of these shelters survived and some did not, statistics to indicate the chance of survival in such structures are not available.
- *Private Basement Shelters.* Private basements were constructed solidly, but most of them lacked the insulating value of very thick walls and the protection of gas-tight construction. Emergency exits (usually leading to another shelter in an adjacent building) could be broken if collapse of the building caused the normal exit to be blocked. As a result of the total destruction in the fire storm area, this precaution was of limited value. Many deaths occurred in these shelters as a result of carbon monoxide poisoning, and the condition of the bodies indicated that intolerable heat followed the carbon monoxide frequently. In some cases, the heat preceded the poisonous gas and was the cause of death. Generally, these shelters offered such a small amount of protection that the occupants were forced out within 10 to 30 minutes. Most of these people were able to move through the streets and escape. Others were forced out later when the fire storm was nearer its peak intensity, and few of these escaped. A few people survived in private basement shelters.

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WT-774

Copy No. 186 A

Operation UPSHOT-KNOTHOLE

NEVADA PROVING GROUNDS

March - June 1953

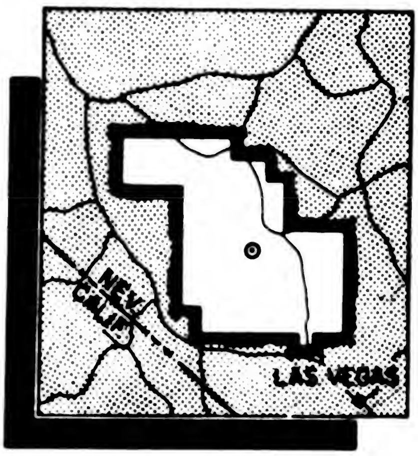
Project 8.11a

INCENDIARY EFFECTS ON BUILDING AND INTERIOR KINDLING FUELS

(ENCORE EFFECT REPORT)

27 kt at 2,423 feet altitude, 19% humidity

(DASA-1251) (Note: cities humidity is ~50-80%)



RESTRICTED DATA

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HEADQUARTERS FIELD COMMAND, ARMED FORCES SPECIAL WEAPONS PROJECT
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

CONFIDENTIAL

Weapon test report WT-774, Project 8.11a, Incendiary effects on buildings and interior kindling fuels

ENCORE test, Nevada, 1953
10' x 12' wooden houses with 4' x 6' windows
17 calories/sq. cm thermal flash

Immediate room flashover during thermal pulse
("Encore effect") in inflammables-filled house
while fire-resistant fabrics in other house survived!

LEFT HOUSE: fire-resistant furnishings
(woolen rugs and clothes, vinyl plastic draperies)

RIGHT HOUSE: non-fire resistant furnishings
plus inflammable magazines and newspapers

Smouldering armchair extinguished 1 hour after detonation, when recovery party arrived at house

November 1963
Second printing May 1964

Unclassified Version

SURVEY OF THE THERMAL THREAT OF NUCLEAR WEAPONS

Prepared for:

OFFICE OF CIVIL DEFENSE
DEPARTMENT OF DEFENSE
WASHINGTON 25, D.C.

By: Jack C. Rogers and T. Miller

SRI Project No. IMU-4021

Approved:

Robert A. Harker

ROBERT A. HARKER, DIRECTOR
MANAGEMENT SCIENCES DIVISION

OCD REVIEW NOTICE

This report represents the authors' views, which in general are in harmony with the technical criteria of the Office of Civil Defense. However, a preliminary evaluation by OCD indicates the need for further evaluation of the fire threat of nuclear weapons and formulation of promising research and action programs.

NOTE: discrepancies are due to HUMIDITY differences.
ENCORE nuclear test (Nevada desert) humidity was ONLY 19%

Table B-VII

COMPARISON OF ESTIMATES FOR IGNITION ENERGY REQUIREMENTS
(10 mt)

Glasstone (1962) The Effects of Nuclear Weapons		Martin, et al. (1959) Naval Radiological Defense Laboratory		
Material	Cal/cm^2 for Ignition	Material	Cal/cm^2 for Ignition	Ratio of NRDL to ENW
Cotton auto seat upholstery, green, brown, white	16	Heavy cotton draperies, dark color	28	1.75
Wool pile chair upholstery, wine	35 (not sustained)	Wool pile chair upholstery, dark color	25	0.7
Newspaper, single sheet	6	Newspaper, medium printed	40	6.7
		Newspaper, dark areas	30	5.
Kraft paper carton, flat side exposed, used, brown	15	Corrugated Kraft board	40	2.6
Deciduous leaves	12	Walnut leaves	54	4.5
		Beech leaves	36	3.
Coarse grass	16	Harding grass	44	2.7
Ponderosa pine needles, brown	18	Pine needles	50	2.7

Sources: Martin, et al. (1959) and Glasstone (1962).

Martin, S. B., On Predicting the Ignition Susceptibility of Typical Kindling Fuels to Ignition by the Thermal Radiation from Nuclear Detonations, Tech. Report 367, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif., April 1959. (U)

Harold L. Brode

The RAND Corporation, Santa Monica, California

P-2745 August 1963

-17-

We have all had the frustrating experience of trying to light a fire with green, moist, or wet wood. Just as wet wood can't be easily induced to burn, so thick combustibles are not easily ignited. Even a dry two-by-four burns reluctantly and stops burning when taken out of the fire. It is a different matter with a shingle or a bunch of kindling! Density also plays a role, a heavier combustible being harder to ignite than lighter-weight material. Of course, the chemistry of the material to the degree that it influences kindling temperatures and flammability, is an important parameter. Modern plastics tend to smoke and boil - to ablate but not to ignite in sustained burning - while paper trash burns readily.

Just as most materials are not particularly sensitive to the sun's thermal radiation, and are not highly inflammable nor even ignitible, the surfaces exposed to the thermal intensity of a nuclear explosion are generally not given to sustained burning. Very intense heat loads may mar or melt surfaces, may char and burn surfaces while the heat is on, but may snuff out immediately afterward.

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PRIMARY AND SECONDARY FIRES FROM NUCLEAR EXPLOSIONS

Although thermal radiation would start many fires in urban and in most suburban areas, such fires by themselves would seldom constitute a source of major destruction. Outside the region of extensive blast damage, fires in trash piles, in dry palm trunks, in roof shingles, in auto and household upholstery, drapes, or flammable stores are normally accessible and readily controllable. By the very fact that these fires start from material exposed to the incident light, they can be easily spotted and, in the absence of other distractions, can be quickly extinguished. Where the blast effects are severe and damage extensive, little effective fire fighting is likely.

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WT-770

This document consists of 64 pages

No. 196 of 295 copies, Series A

AD B951673

OPERATION UPSHOT-KNOTHOLE

Project 8.5

THERMAL RADIATION PROTECTION AFFORDED TEST ANIMALS BY FABRIC ASSEMBLIES

REPORT TO THE TEST DIRECTOR

by

J. Fred Oesterling and Staff

UNCLASSIFIED

REGRADED UNCLASSIFIED

BY AUTHORITY OF DA FORM 1575 FCAG 274/24 26 Aug 63

BY B. W. ... 23 Sep 64

July 1955

~~FORMERLY RESTRICTED DATA~~

Handle As Restricted D[redacted]in Foreign Dissemination S[redacted]on 144B, Atomic [redacted]

REST[redacted] DATA

[redacted] contains restricted data as defined in [redacted] Energy Act of 1954. Its transmittal or [redacted]e of its contents in any manner to an una[redacted]rized [redacted]

Quartermaster Research and Development Laboratories
Army Medical Service Graduate School
Walter Reed Army Medical Center
University of Rochester Atomic Energy Project

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4.1.2 Factors Contributing to the Greater Degree of Thermal Protection in the Field.

There are several conditions encountered in the field, especially at the higher energy levels, but not duplicated in the laboratory (at least not up to the present time) that may account for the fact that like amounts of thermal energy did not produce comparable results in the laboratory and in the field. First, the thermal energy is delivered much more rapidly with the explosion of an atomic bomb than it is in the laboratory. Second, due to smoke obscuration the animals in the field actually received a smaller percentage of the total energy delivered than they did in the laboratory. Third, the blast wave following the explosion tended to extinguish flames and remove char, whereas no such wave was present in the laboratory tests. Fourth, where the heat reached the fabric layer next to the skin, uniform drape (or spacing) provided additional protection in the field.

(2) Motion pictures of clothed animals, exposed to 50.0 and 33.5 cal/cm^2 on Shots 9 and 10 respectively, showed heavy clouds

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of black smoke enveloping the animals within 120 ms of the explosion.

(3) The blast wave following the explosion, which has not been duplicated in laboratory applications of thermal energy, has two possible protective effects. First, it can be expected to extinguish flames induced by the radiation in assemblies not treated for fire resistance, thus removing a source of high heat. Although the blast wave may not actually extinguish the flame in all cases,* it can be expected in general to have this effect. Second, the blast wave would tend to remove any char which, if allowed to remain, would act as a heat reservoir and increase the likelihood of a severe burn.

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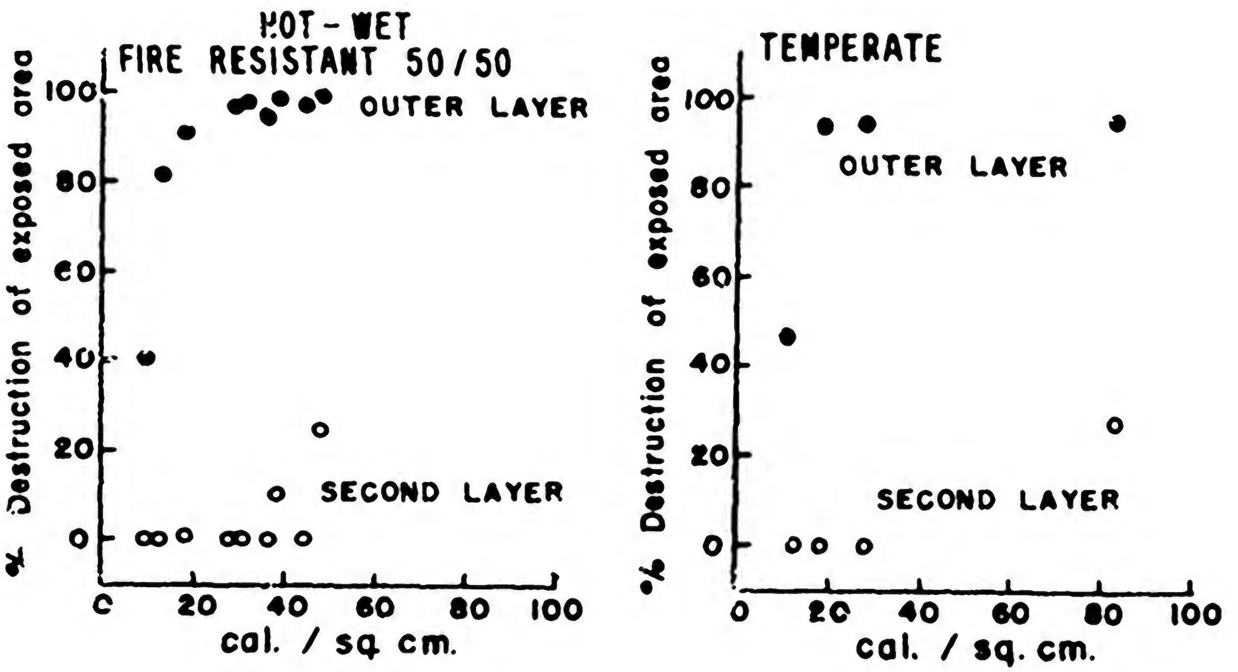
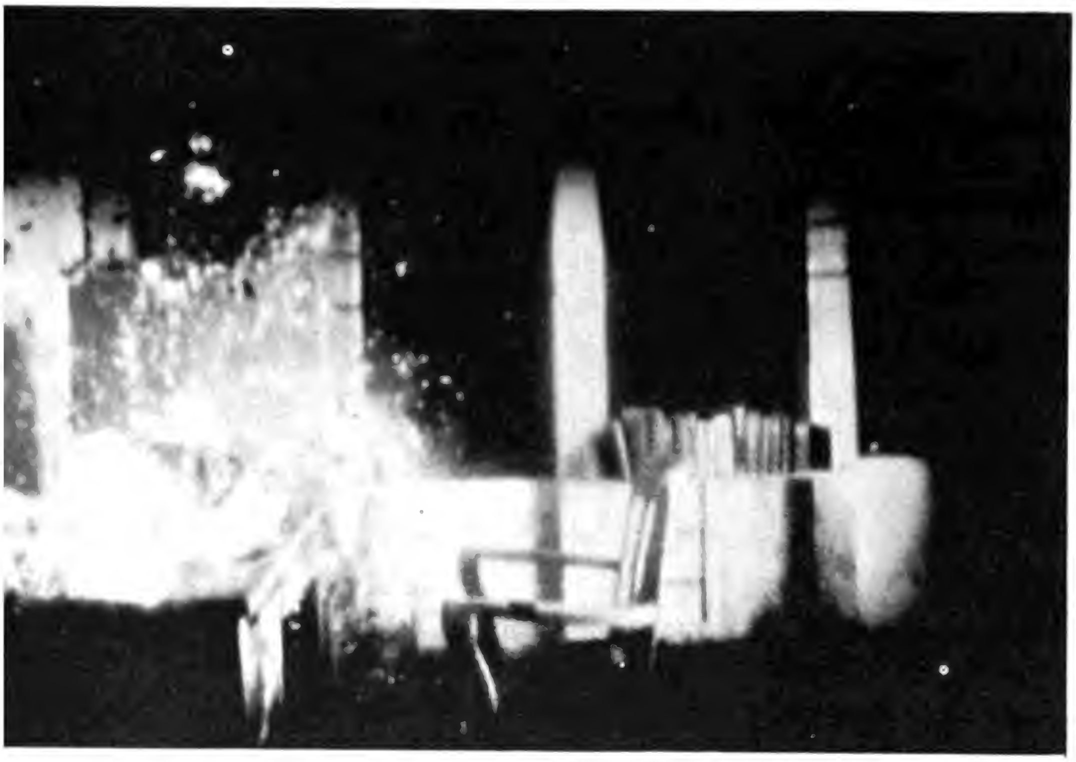
Fig. 3.5 Destruction of Outer and Second Layers of Pigs' Uniforms (Shots 9 and 10)



EFFECTS OF 1 PSI OVERPRESSURE ON IGNITIONS

From: <u>Goodale, Effects of Air Blast on Urban Fires</u>
URS 7009–14 Dec. 1970
(AD 723 429)



Blast winds both cool burning material and upset flame convection system.

50% of burning curtains are extinguished by 1 psi overpressure

100% are put out by 2.5 psi. Note that burning LIQUIDS in high-wall trays are not put out by blast waves, but this is not relevant to city fires.

Burning beds can continue to smoulder until extinguished with water.

cue for survival

OPERATION CUE

A.E.C. NEVADA TEST SITE

MAY 5, 1955

A report by the FEDERAL CIVIL DEFENSE ADMINISTRATION

EFFECTS OF NUCLEAR WEAPONS

BY HAROLD L. GOODWIN,
Director, Atomic Test Operations, FCDA

The time of travel of the shock wave is not generally understood by many persons. The concept of "duck and cover," which would still be of great value in case of attack without warning, is based on the comparatively large time interval between the burst and arrival of the shock wave at a given point.

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BIOMEDICAL EFFECTS OF THERMAL RADIATION

BY DR. HERMAN ELWYN PEARSE, *Professor of Surgery at the University of Rochester. Consultant to several Government departments, notably the Atomic Energy Commission's Division of Biology and Medicine. Consultant to the Armed Forces Special Weapons Project*

After the Bikini test, I was asked to go to Japan as a consultant for the National Research Council to survey the casualties in Nagasaki and Hiroshima.

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Then we observed the healing of the wounds, and we found again that the wounds healed in the same manner as those that we had produced in the laboratory. There was some difference in these lesions from the ordinary burns of civil life, but I would predict, from what I learned from experiments, that the difference is on the good side. The burns look worse; they are often charred, but they may not penetrate as deeply, and the char acts as a dressing, nature's own dressing.

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For example, if you have 2 layers, an undershirt and a shirt, you will get much less protection than if you have 4 layers; and if you get up to 6 layers, you have such great protection from thermal effects that you will be killed by some other thing. Under 6 layers we only got about 50 percent first degree burns at 107 calories.

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If we can just increase the protection a little bit, we may prevent thousands and thousands of burns.

... For example, to produce a 50-percent level of second-degree burns on bare skin required 4 calories. When we put 2 layers of cloth in contact, it only took 6 calories. But separate that cloth by 5 millimeters, about a fifth of an inch, and it increases the protective effect 5 times. The energy required to produce the same 50-percent probability of a second-degree burn is raised up to 30 calories. So if you wear loose clothing, you are better off than if your wear tight clothing.

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Abridged

THE BURN SURFACE AS A PARASITE

WATER LOSS, CALORIC DEMANDS, AND THERAPEUTIC IMPLICATIONS

Carl Jelenko, III, M.D.

Department of Surgery

University of Maryland School of Medicine and Hospital

Baltimore, Maryland

Water is Lost through Burned Skin

If, during the first 48 hours after injury, no more fluid is given to an extensively burned patient than he would need in health, the uncompensated loss of fluid from his circulation may cause shock, and if sufficiently severe, death.

Heat is Lost Necessitating a High Food Intake

To make matters worse, evaporation of moisture from the wound surface saps not only the body's water stores but its energy stores as well. When water evaporates from the burned surface, cooling results and the body loses heat. The larger the burn wound, the more water loss and the more heat or energy loss.

How Can the Fluid and Heat Losses Be Diminished?

Think Plastic Wrap as Wound Dressing for Thermal Burns

ACEP (American College of Emergency Physicians) News
http://www.acep.org/content.aspx?id=40462

August 2008
By Patrice Wendling
Elsevier Global Medical News

CHICAGO - Ordinary household plastic wrap makes an excellent, biologically safe wound dressing for patients with thermal burns en route to the emergency department or burn unit.

The Burn Treatment Center at the University of Iowa Hospitals and Clinics, Iowa City, has advocated prehospital and first-aid use of ordinary plastic wrap or cling film on burn wounds for almost two decades with very positive results, Edwin Clopton, a paramedic and ED technician, explained during a poster session at the annual meeting of the American Burn Association.

Dr. G. Patrick Kealey, newly appointed ABA president and director of emergency general surgery at the University of Iowa Hospital and Clinics, said in an interview that plastic wrap reduces pain, wound contamination, and fluid losses. Furthermore, it's inexpensive, widely available, nontoxic, and transparent, which allows for wound monitoring without dressing removal.

THE UNITED STATES
STRATEGIC BOMBING SURVEY

THE EFFECTS OF THE ATOMIC BOMB ON HIROSHIMA, JAPAN

Volume I

Physical Damage Division

May 1947

G. CAUSE AND EXTENT OF FIRE

1. Conditions Prior to Attack

The city of Hiroshima was an excellent target for the atomic bomb from a fire standpoint: There had been no rain for three weeks; the city was highly combustible, consisting principally of Japanese domestic-type structures; it was constructed over flat terrain; and 13 square miles (including streets) of the 26.5-square-mile city was more than 5 percent built up (i. e., covered by plan areas of buildings). The remainder of the city comprised water areas, parks and areas built up below 5 percent. Sixty-eight percent of the 13-square-mile area was 27 to 42 percent built up and the 4-square-mile city center was particularly dense, 93.6 percent of it being 27 to 42 percent built up.

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a. Evidence relative to ignition of combustible structures and materials by heat directly radiated by the atomic bomb and by other ignition sources developed the following: (1) The primary fire hazard was present in combustible materials and in fire-resistive buildings with unshielded wall openings; (2) six persons who had been in reinforced-concrete buildings within 3,200 feet of air zero stated that black cotton black-out curtains were ignited by radiant heat; (3) a few persons stated that thin rice paper, cedarbark roofs, thatched roofs, and tops of wooden poles were afire immediately after the explosion; (4) dark clothing was scorched, and, in some cases, reported to have burst into flame from flash heat; (5) but a large proportion of over 1,000 persons questioned was in agreement that a great majority of the original fires was started by debris falling on kitchen charcoal fires, by industrial process fires, or by electric short circuits.

b. Hundreds of fires were reported to have started in the center of the city within ten minutes after the explosion. Of the total number of buildings investigated 107 caught fire, and, in 69 instances, the probable cause of initial ignition of the buildings or their contents was established as follows: (1) 8 by direct radiated heat from the bomb (primary fire), (2) 8 by secondary sources and (3) 53 by fire spread from exposing buildings.

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3. Conditions on Morning of Attack

a. The morning of 6 August 1945 was clear with a small amount of clouds at high altitude. Wind was from the south with a velocity of about 4½ miles per hour. Visibility was 10 to 15 miles.

(1) Only a few persons remained in the air-raid shelters after the "all-clear" sounded.

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THE UNITED STATES
STRATEGIC BOMBING SURVEY

THE EFFECTS OF THE ATOMIC BOMB ON HIROSHIMA, JAPAN

Volume II

Physical Damage Division

Dates of Survey:

14 October–26 November 1945

Date of Publication

May 1947

4. The city, consisting principally of Japanese domestic structures, was highly combustible and densely built up. Sixty-eight percent of the 13-square-mile city area was 27 to 42 percent built up and the 4-square-mile city center was particularly dense, 94 percent of it being 27 to 42 percent built up. All the large industrial plants were located on the south and southeast edges of the city.

8. Evidence relative to ignition of combustible structures and materials by directly radiated heat from the atomic bomb and other ignition sources was obtained by interrogation and visual inspection of the entire city. Six persons who had been in reinforced-concrete buildings within 3,200 feet of air zero stated that black cotton black-out curtains were ignited by flash heat. A few persons stated that thin rice paper, cedarbark roofs, thatched roofs, and tops of wooden poles were afire immediately after the explosion. Dark clothing was scorched and, in some cases, was reported to have burst into flame from flash heat. A large proportion of over 1,000 persons questioned was, however, in agreement that a great majority of the original fires were started by debris falling on kitchen charcoal fires. Other sources of secondary fire were industrial-process fires and electric short circuits.

9. There had been practically no rain in the city for about 3 weeks. The velocity of the wind on the morning of the atomic-bomb attack was not more than 5 miles per hour.

10. Hundreds of fires were reported to have started in the center of the city within 10 minutes after the explosion.

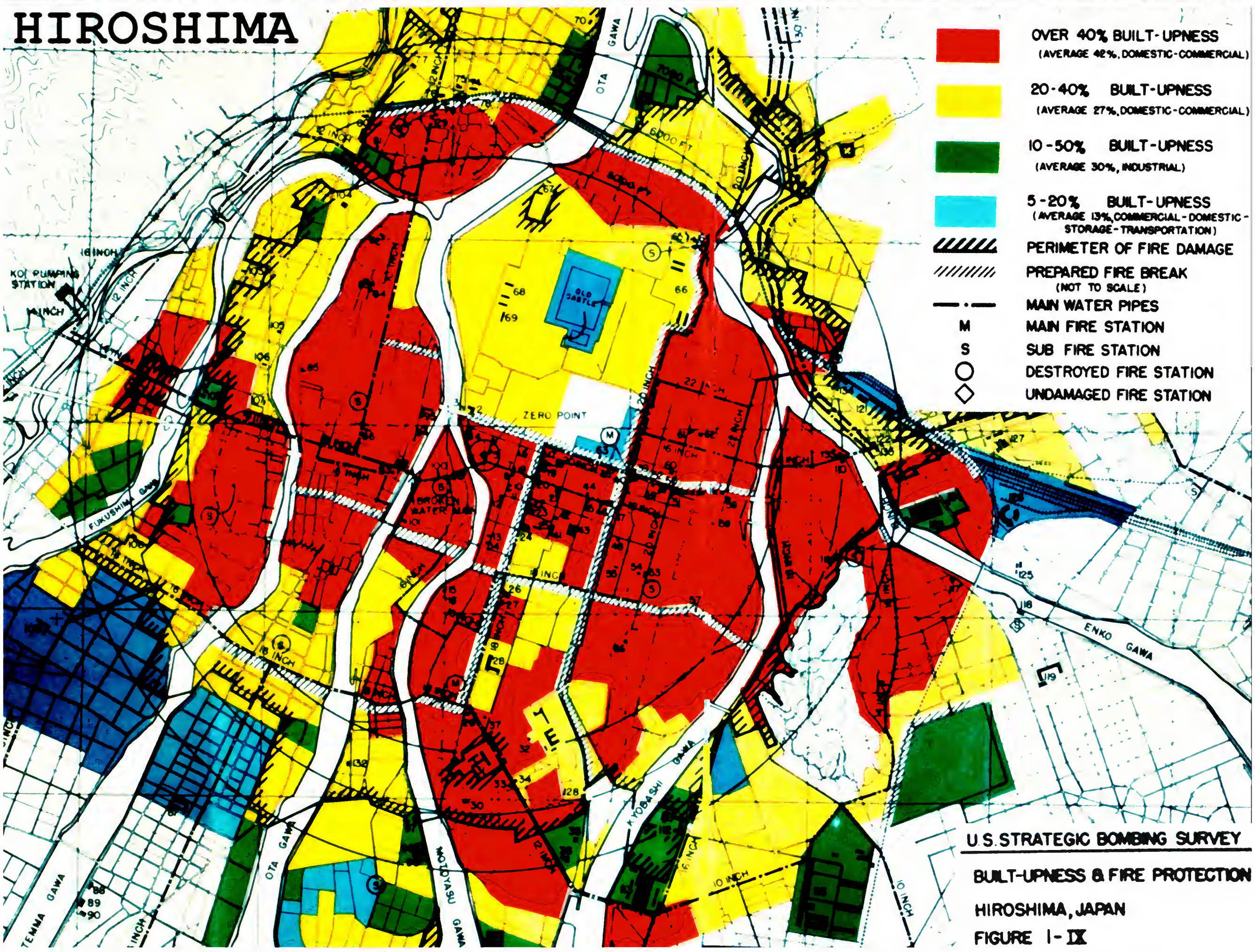
4

PHOTO 36 IX. Shows partly burned coat of boy who was in open near City Hall (Building 28) 3,800 feet from AZ.

(8) Scores of persons throughout all sections of the city were questioned concerning the ignition of clothing by the flash from the bomb. Replies were consistent that white silk seldom was affected, although black, and some other colored silk, charred and disintegrated. Numerous instances were reported in which designs in black or other dark colors on a white silk kimono were charred so that they fell out, but the white part was not affected. These statements were confirmed by United States medical officers who had been able to examine a number of kimonos available in a hospital. Ten school boys were located during the study who had been in school yards about 6,200 feet east and 7,000 feet west, respectively, from AZ. These boys had flash burns on the portions of their faces which had been directly exposed to rays of the bomb. The boys' stories were consistent to the effect that their clothing, apparently of cotton materials, "smoked," but did not burst into flame. Photo 36 shows a boy's coat that started to smolder from heat rays at 3,800 feet from AZ.

(3300 from GZ)

24



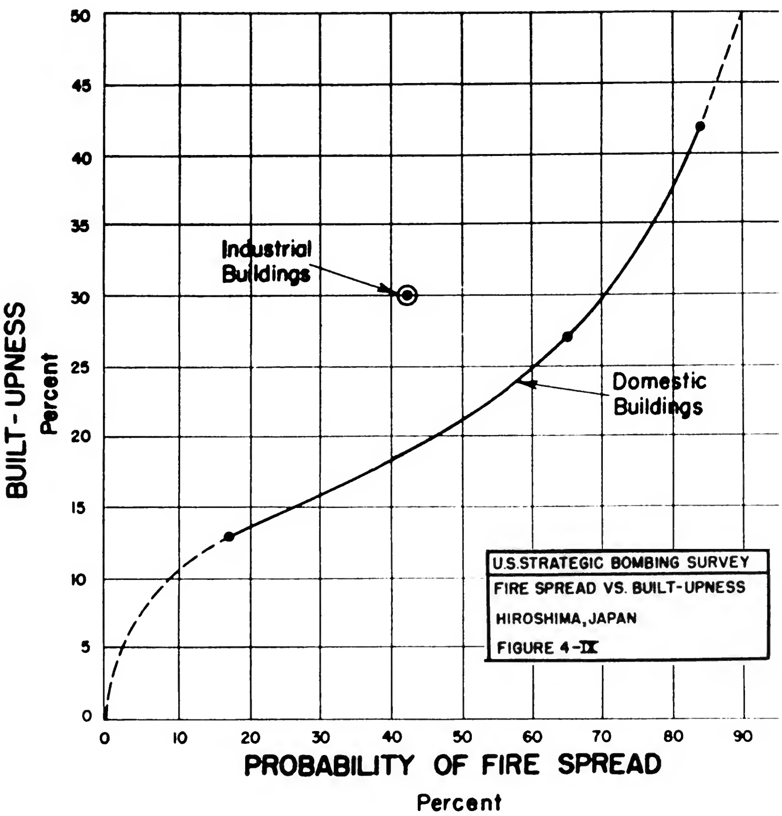
SOURCE: USSBS's report, "The Effects of the Atomic Bomb on Hiroshima, Japan," vol. 2
Only 8 of 64 non-wood buildings had thermal flash ignition evidence, 3
had blast damage induced fire, and 28 were ignited by firespread from wood homes.

D. THE CONFLAGRATION

1. Start of Fire

b. Direct Ignition by the Atomic Bomb. (1) Six persons were found who had been in reinforced-concrete buildings within 3,200 feet of AZ at the time of the explosion and who stated that black cotton black-out curtains were blazing a few seconds later. In two cases it was stated that thin rice paper on desks close to open windows facing AZ also burst into flame immediately, although heavier paper did not ignite. No incidents were recounted to the effect that furniture or similar objects within buildings were ignited directly by radiated heat from the bomb.

21



(4) It was reported that a cotton black-out curtain at an unprotected window in the east stair tower of Building 85 (3,800 feet from AZ) smoked and was scorched by radiated heat from the bomb but it did not burst into flames.

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(5) A man who was in the third story of building 26 (3,000 feet from AZ) stated that radiated heat from the bomb ignited cotton black-out curtains at unprotected windows in the west wall and thin rice paper on desks.

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(10) Fire fighting with water buckets was reported inside only four buildings (24, 33, 59, and 122) and probably prevented extensive fire damage in them. In Building 24, fire was started in contents of a room at the southwest corner of the second story by sparks from trees on the south side about 1½ hours after the attack. Men inside the building extinguished the fire and probably prevented further damage in the first and second stories (Photo 85). A little later, contents in the third story were ignited by sparks from the outside and were totally damaged. This fire was beyond control before it was discovered, but did not spread downward through open stairs. At Building 33, sparks from the west exposure, which burned in early evening, set fire to black-out curtains in the west wall and to waste paper in the fourth story of the northwest section of the building. Twenty persons were on guard in the building awaiting such an occurrence and the fires were quickly extinguished while in the incipient stage. At Building 59 sparks from the south exposure ignited a few pieces of furniture in the first and third stories and black-out curtains in the first story about 2 hours after the attack. These fires were extinguished by men inside and negligible damage resulted. A few window frames in the east and west walls and 2 or 3 desks in the first story of Building 122 were ignited by radiated heat and sparks from the west and northeast exposures. These fires were extinguished quickly and damage was negligible.

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A. SUMMARY

4. The mean areas of effectiveness (MAE) of the atomic bomb for structural damage about ground zero (GZ) and the radii of the MAE's for the several classes of buildings present were computed to be as follows:

	MAE's in square miles	Radii of MAE's in feet
Multistory, earthquake-resistant	0. 03	500
Multistory, steel- and reinforced-concrete frame (including both earthquake- and non-earthquake-resistant construction)	. 05	700
1-story, light, steel-frame	3. 4	5, 500
Multistory, load-bearing, brick-wall	3. 6	5, 700
1-story, load-bearing, brick-wall	6. 0	7, 300
Wood-frame industrial-commercial (dimension-timber construction)	8. 5	8, 700
Wood-frame domestic buildings (wood-pole construction)	9. 5	9, 200
Residential construction	6. 0	7, 300

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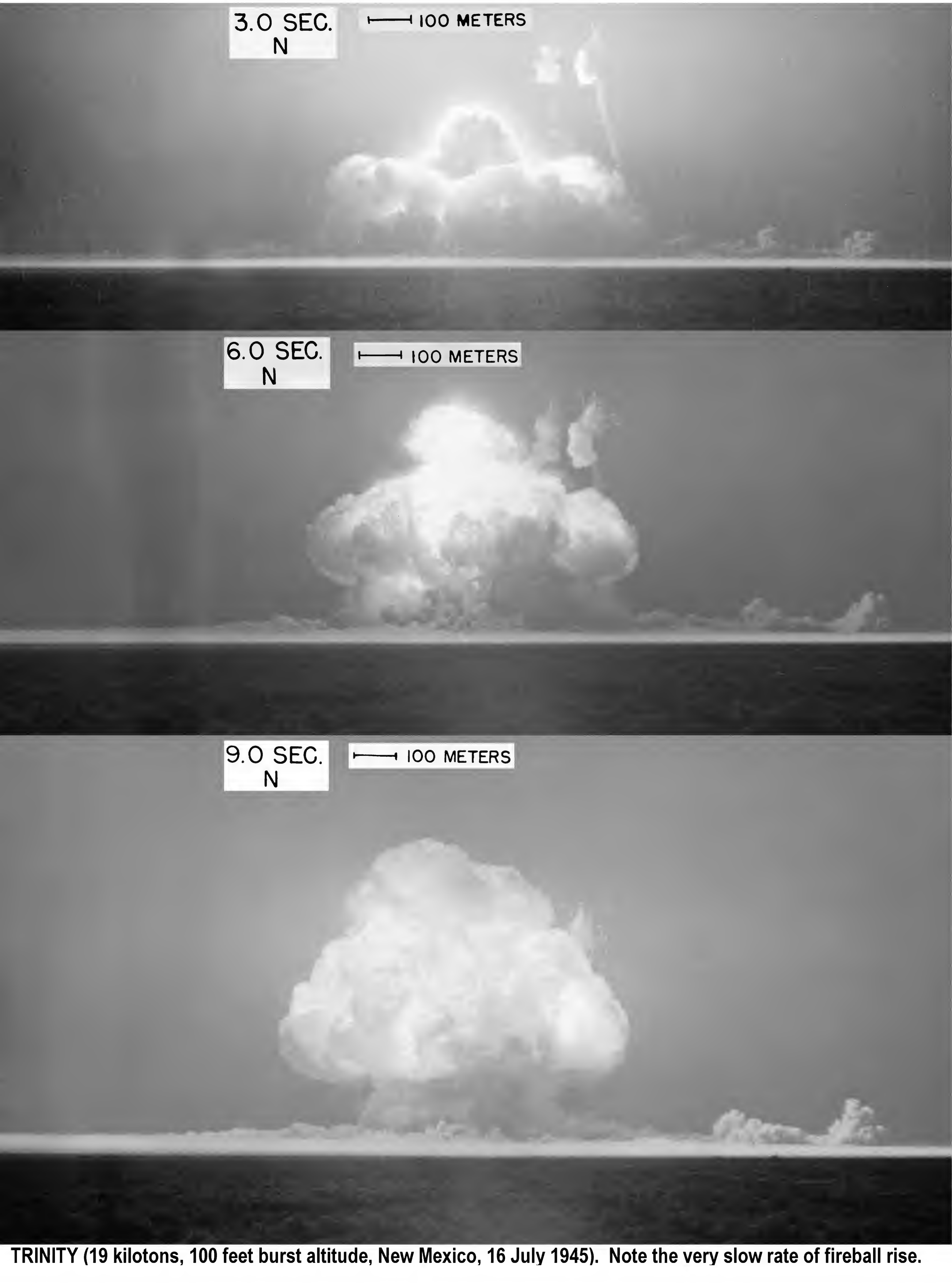
BANK OF JAPAN BUILDING AFTER ATTACK ON HIROSHIMA

GEIBI BANK CO. BUILDING AFTER ATTACK ON HIROSHIMA

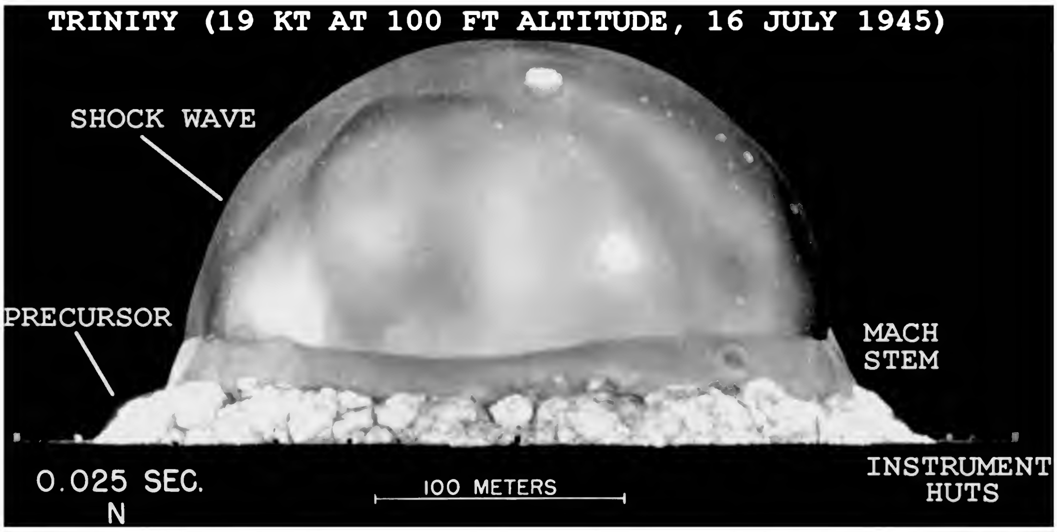
Bank of Japan: USSBS Building 24, 1300 ft from GZ
Geibi Bank Co: USSBS Building 59, 4100 ft from GZ
(Table 5 of USSBS report 92 Hiroshima, v2.)

In both, survivors extinguished fire with water buckets.

(Ref: Panel 26 of the "DCPA Attack Environment Manual", Chapter 3.)



TRINITY (19 kilotons, 100 feet burst altitude, New Mexico, 16 July 1945). Note the very slow rate of fireball rise.


TRINITY (19 KT AT 100 FT ALTITUDE, 16 JULY 1945)
SHOCK WAVE
PRECURSOR
MACH
STEM
0.025 SEC.
N
100 METERS
INSTRUMENT
HUTS


PRECURSOR DUST CLOUD ABSORBS FIREBALL BASE HEAT FLASH
1.0 SEC.
N
100 METERS


TOWER BASE, 1.4 R/HOUR
11 SEPTEMBER 1945

RESEARCH TRIANGLE INSTITUTE
Durham, North Carolina

Final Report R-85-1

CRASH CIVIL DEFENSE PROGRAM STUDY

by

K. E. Willis
E. R. Brooks
L. J. Dow

April 30, 1963

Prepared for

OFFICE OF CIVIL DEFENSE
UNITED STATES DEPARTMENT OF DEFENSE

Feasibility

In the typical household, some materials will generally be available for covering windows against thermal radiation. One half roll of aluminum foil would cover about 25 ft^2 and would provide very effective covering for 1 to 2 windows (those most likely to face the blast). Sufficient quantities of either light colored paint, Bon Ami, or whiting would be available in most households to cover windows. Aluminum screens attenuate from 30 - 50% of the thermal radiation and hence screens should be closed or installed.

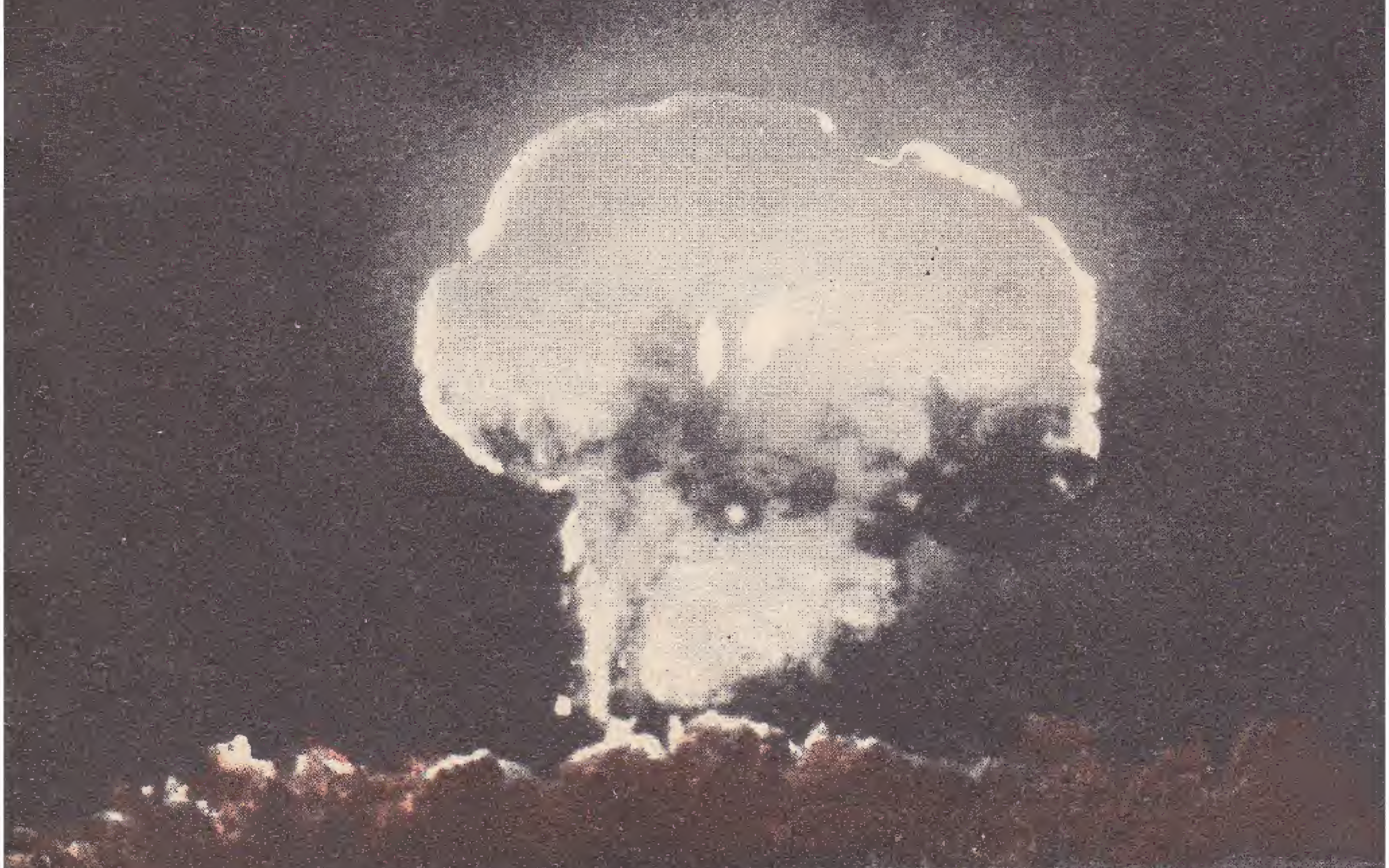
The amount of water per square foot required to dissipate 25 cal/cm^2 of thermal radiation can quickly be calculated from the heat of vaporization of water (580 cal/gm). Allowing 90% losses due to absorption or spillage, one gallon of water is sufficient to wet 10 ft^2 of material so that it can withstand 25 cal/cm^2 of direct thermal radiation (i.e., the radiation is normal to the material surface at all points). Since the average daily water consumption per service (Reference 3) is about 700 gallons, it is apparent that the wetting of interior flammables (piled up curtains, furniture, etc.) is feasible in most cases when used in conjunction with the other measures.

3. Statistical Abstracts of the United States. Washington: U. S. Government Printing Office, 1962.

Weapon test report WT-775, Project 8.11b, ENCORE nuclear test, Nevada, 1953:

6' x 6' wood frame houses

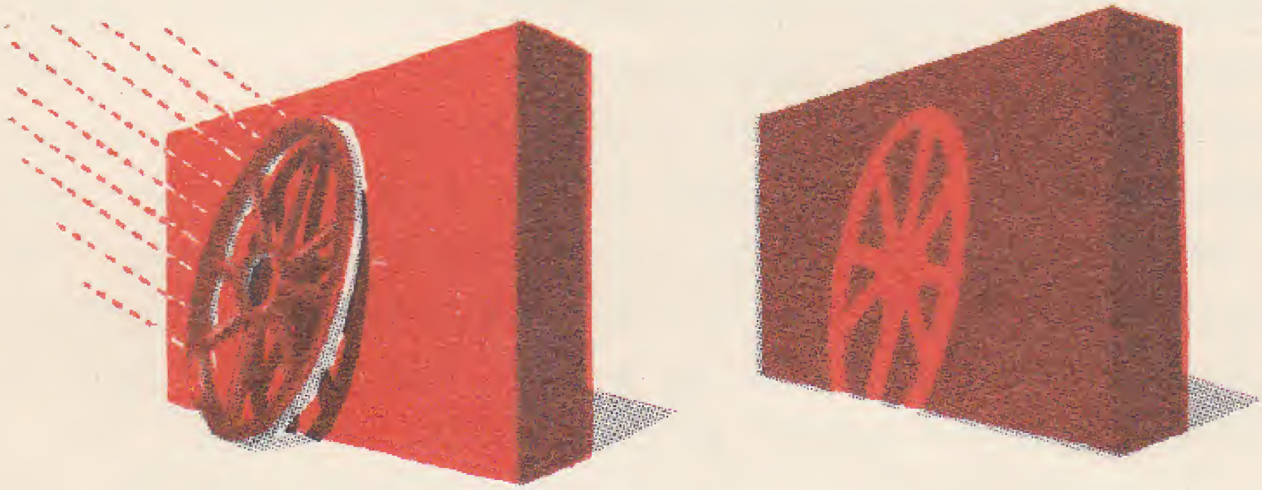
The Hydrogen Bomb



HER MAJESTY'S STATIONERY OFFICE

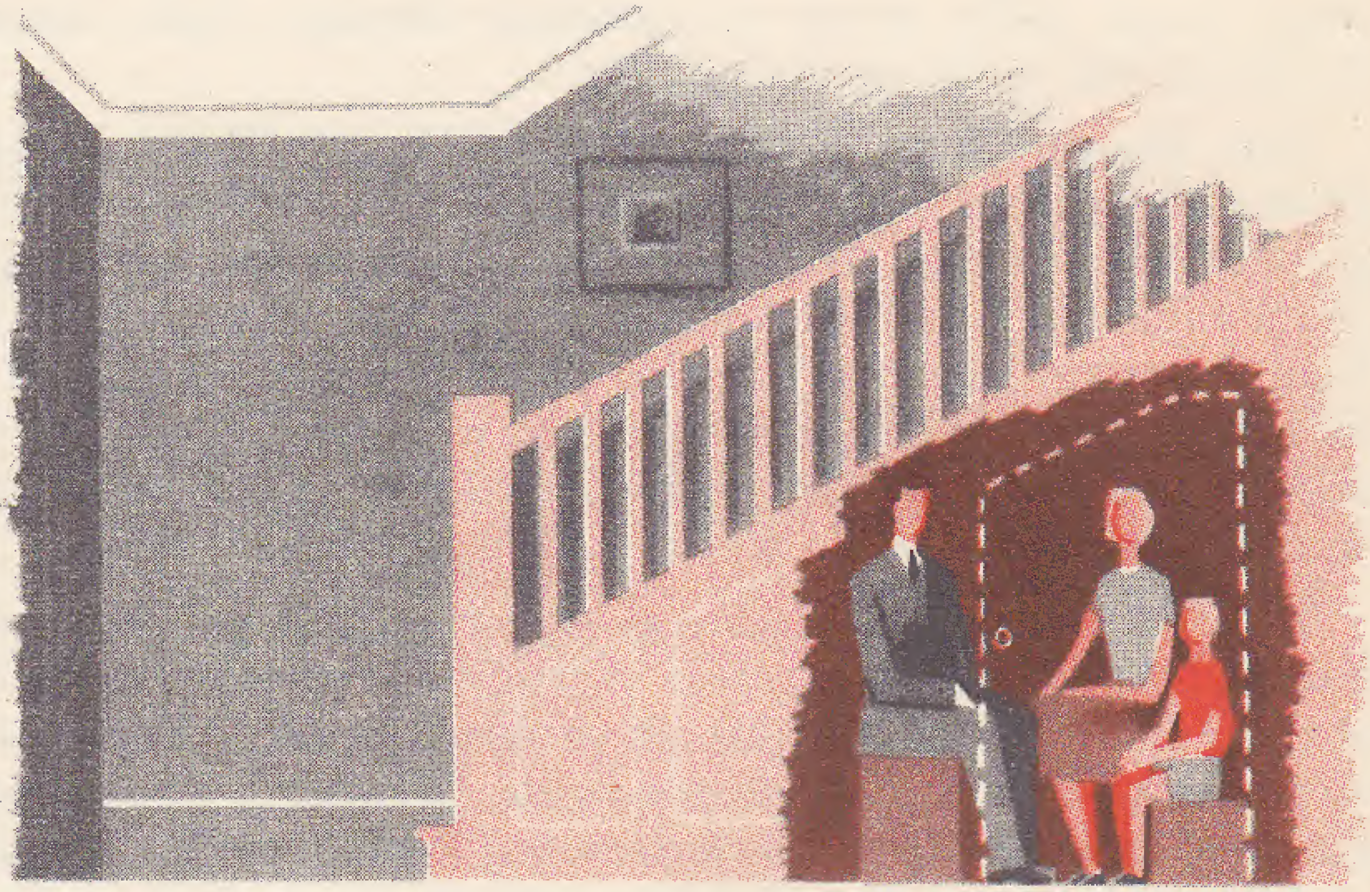
NINEPENCE NET

Anything that keeps off the sun's heat will help to give protection against the heat of a nuclear bomb. At Hiroshima, for instance, a painted surface was scorched except where it was in the shadow of a wheel.



The protection given by clothing depends on the distance from the explosion. The chances of escaping serious burns are increased by wearing hat and gloves and slacks or trousers. At Hiroshima some Japanese women, who had on white cotton dresses with a darker pattern, suffered burns only beneath the pattern. The skin under the white material escaped. This was because white or light-coloured material reflects heat while dark material absorbs it. Colour apart, woollen clothes would be less likely to catch fire than cotton. If clothing did catch fire and there was no time to throw it off, the best way to put out the flames would be to roll over and over on the ground.

All this applies only to people caught in the path of the heat rays. Any solid substance would give full protection against this danger, and a few minutes' warning of the attack would give people time to take cover. Even if they had not heard a warning, people at a distance who took cover even a few seconds after the explosion of a hydrogen bomb would escape some of the heat.



The stairs would give some protection against falling debris

Best at resisting pressure are heavily framed steel and reinforced concrete buildings or those with rounded streamlined surfaces. In Nagasaki, for instance, most of the tall factory chimneys survived.

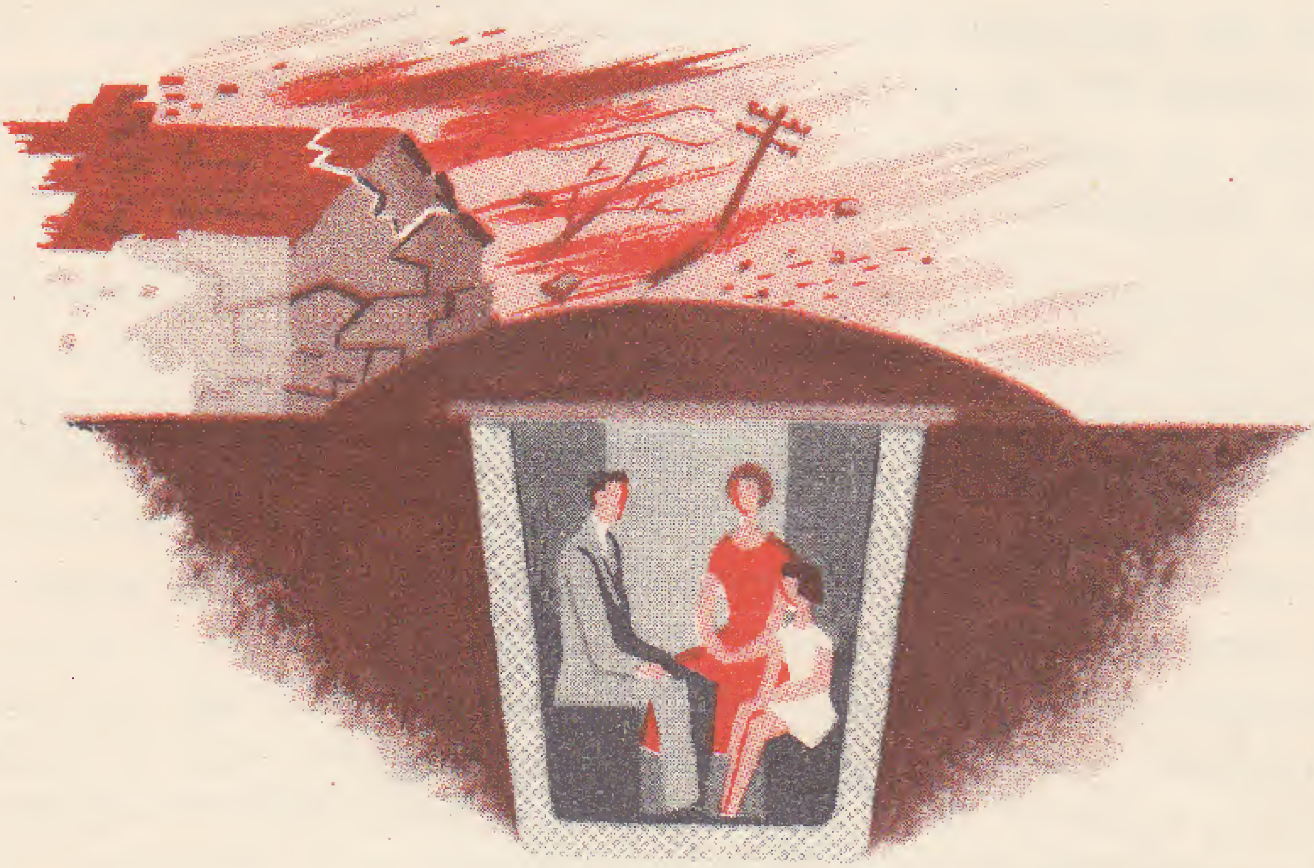
THE DANGER TO PEOPLE

At Hiroshima and Nagasaki very few injuries, such as perforated ear-drums, were caused directly by the blast itself. The real danger is that people would be struck by falling masonry, flying debris or fragments of glass, or might themselves be thrown against some object.

The warning system, however, is designed to enable people to get under cover. A slit trench, especially if covered with a

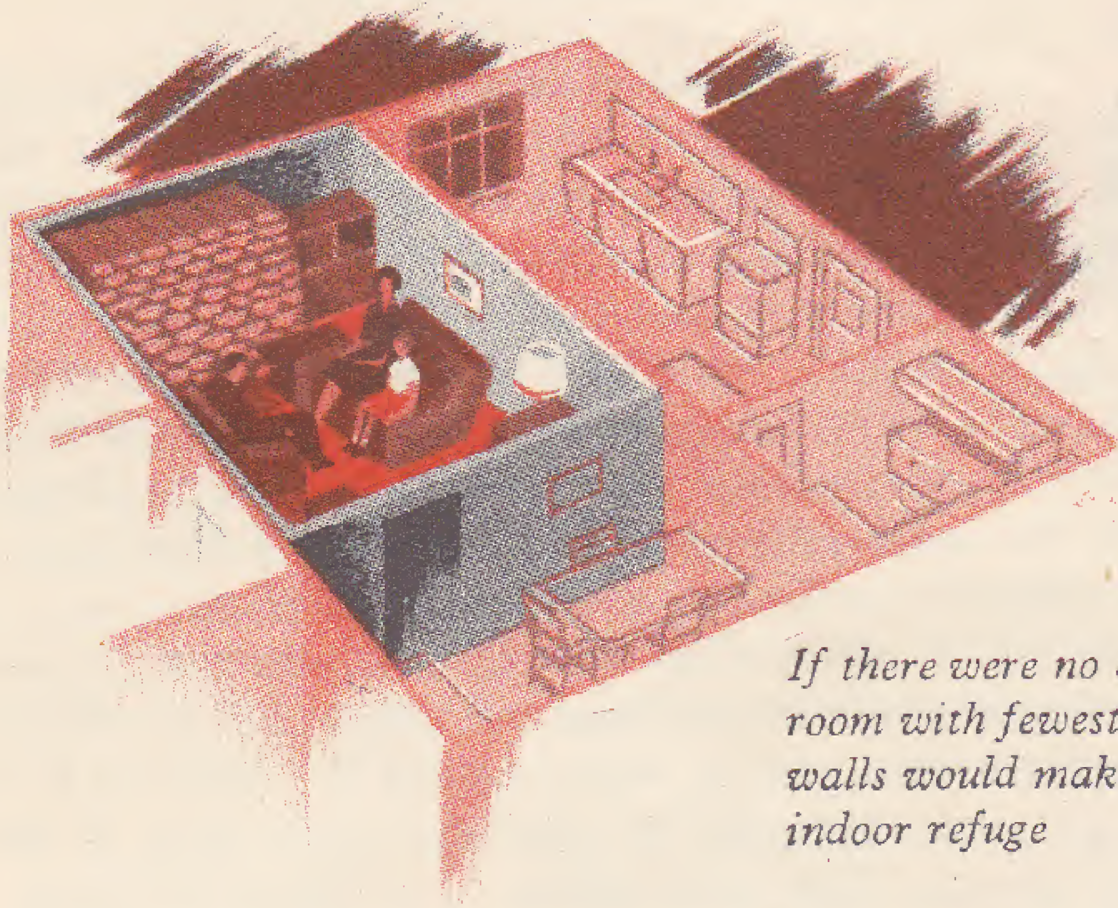
few feet of earth, or a cellar or basement would give good protection. If there were no cellar or basement it would be safest under the stairs, or under a table or bed which would give some protection should the roof or ceiling collapse ; and if there were no time to reach such places before the flash is seen, the best place indoors would be close to an inside wall, avoiding windows or anywhere in the possible path of flying glass.

People caught unprotected in the open could at least try to shelter from the rubble and flying debris, if only in doorways or behind walls or even trees. Failing this, they could fall flat on the ground, with the head and face covered, if possible close to the wall of a substantial building, or in a nearby ditch or gutter.



A slit trench with earth covering protects against blast and radiation

A prepared refuge room inside a house could be made to give good protection against fall-out (although not so good as a covered slit trench) and it would also be much less uncomfortable for a period of two days or more. A cellar or basement would be by far the best place for a refuge room ; next best would be the room with the fewest outside walls and the smallest windows. The windows would need to be blocked with solid material, to the thickness of the surrounding walls at least. It would help if the walls themselves were thickened, not necessarily to their full height, with sandbags, boxes filled with earth, or heavy furniture. The occupants of the refuge room would have to remain in it until told that it was safe to come out—perhaps for a period of days—and the room would have to be prepared and equipped accordingly.



If there were no cellar, the room with fewest outside walls would make the best indoor refuge

In some places it might be practicable to make good use of both an outdoor slit trench and an indoor refuge room, using the first for protection against blast, and the second, if the house survived the blast, for subsequent protection against fall-out.

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